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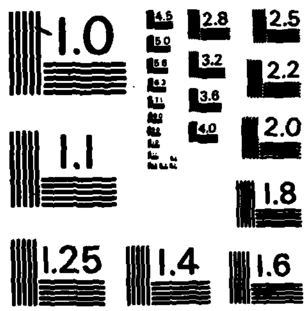

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DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
R.A.N. RESEARCH LABORATORY
EDGECLIFF, N.S.W.

RANRL TECHNICAL MEMORANDUM
(EXTERNAL) No. 8/83

COMPARISONS OF SEA-SURFACE TEMPERATURE OBTAINED FROM SHIP AND SATELLITE DATA (U)

L.J. HAMILTON

Technical Memoranda are of a tentative nature, representing the views of the author(s), and do not necessarily carry the authority of the Laboratory.

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COMPARISONS OF SEA SURFACE TEMPERATURE OBTAINED FROM SHIP AND SATELLITE DATA

L.J. HAMILTON

ABSTRACT

Sea-surface-temperatures (SST) obtained by thermosalinograph on five cruises during the period 23 September 1982 to 30 January 1983 in waters east and north-east of the Australian coastline are compared graphically with SST obtained from three sources of satellite data, GOSSTCOMP charts (Global Operational Sea Surface Temperature Computation), NWS charts (National Weather Service), and GMS (Geostationary Meteorological Satellite) tables. The data is plotted as temperature versus cumulative ship distance travelled. For these cruises, fronts and features were seldom discernible in the satellite data but broad scale average trends were well shown. GOSSTCOMP was found to be the most reliable temperature indicator, often closely following the graph of highly smoothed ship temperature. NWS often tended to follow peak temperatures while GMS often overestimated SST by more than 3°C. Estimates are given on the usefulness of absolute values of satellite SST in real-time analyses.

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CONTENTS

1. INTRODUCTION

Sea-surface temperatures (SST) obtained by thermosalinograph on five cruises during the period 23 September 1982 to 30 January 1983 in waters east and north-east of the Australian coastline are compared graphically with SST obtained from three sources of satellite data, GOSSTCOMP (Global Operational Sea Surface Temperature Computation) temperature charts, NWS (National Weather Service) temperature charts, and GMS (Geostationary Meteorological Satellite) tables. The data is plotted as temperature versus cumulative ship distance travelled to allow ready visual identification of temperature fronts and features.

The start of the time period corresponds to the GOSSTCOMP resolution being significantly improved (Pichel, 1982), to the extent where possible eddy patterns could be seen off the East Australian coast (see Fig. 1(a)). (The eddy pattern was also shown on Naval Air Station (NAS) Nowra analyses for this area obtained from XBT's and GMS satellite images).

Satellite data and products are often available on a daily basis and this memorandum will attempt to give some idea as to their usefulness in detailed SST analyses, such as those produced by NAS Nowra for the area off the East Australian coast. In particular some SST values from NOAA satellites averaged over 50 km resolution target arrays and corrected for atmospheric effects by multispectral techniques are available in "real-time" via telex over the World Meteorological Office Global Telecommunications System (GTS). These values are used by NOAA to produce GOSSTCOMP SST values (Pichel, 1980). "Real-time" is within 8 hours of acquisition of satellite data by ground station. The accuracy of GOSSTCOMP is therefore worth assessing. GMS data is also available over GTS every ten days. Some SST data are obtained by ship routinely but coverage is very sparse.

This memorandum is therefore concerned with possible real-time applications of the satellite data sources, as well as their application to oceanographic analyses of areas at later times.

The extent to which SST patterns can reflect the position of major fronts and eddies, and surface mixed-layer-depth in the western Tasman Sea is discussed in Mulhearn and Hamilton (1982).

.../2. PURPOSE OF

2. PURPOSE OF COMPARISON OF SHIP AND SATELLITE SST

The satellite data may be evaluated with respect to the following:

Agreement of absolute satellite SST values with sea-truth values.

Ability to discern fronts and other mesoscale features.

Resolution of smaller scale features.

Agreement between satellite data sets.

Performance in areas of high variability.

Agreement with claimed accuracy.

Performance near land masses and islands.

The above may give a guide to the reliability of each set of satellite data for particular purposes, e.g. NAS Nowra analyses, and may show if data sets from the different satellites can be combined to give a better indication than any one set, as well as giving some estimate of the temperature and spatial resolution.

3. METHOD OF COMPARISON OF DATA SETS

The four data sets for each cruise are plotted on the same figure as SST(^{o}C) versus the cumulative ship distance travelled (nautical miles). See Figs. 8 to 12. This enables fronts, fluctuations and trends in the data to be readily seen and compared. The cruise tracks are given in Figs. 4 to 7.

Capital letters A, B, C, ... shown at turning points on the cruise tracks are also shown on the SST plots on the cumulative distance travelled axis.

.../4. DATA SOURCES

4. DATA SOURCES

A. SHIP DATA

The sea-truth data was obtained from thermosalinograph traces, usually at hourly intervals, roughly corresponding to six nautical mile spacing, for ship speed of 10 knots, from CSIRO cruises on R.V. Sprightly. Latitude-longitude is obtained from a satellite navigation system. Temperature values are generally accurate within 0.2^{o}C. The thermosalinograph input is 2 metres below the sea-surface.

Records were obtained from the following CSIRO cruises on R.V. Sprightly:

Cruise	Date
SP10/82	29 Sep - 14 Oct 82
SP11/82	16 Oct - 27 Oct 82
SP12/82	1 Dec - 9 Dec 82
SP 1/83	16 Jan - 26 Jan 83
SP 2/83	27 Jan - 30 Jan 83

The cruise tracks are shown in Figs. 4 to 7.

The five cruises covered approximately 7650 n.m. in 52 whole or part days. Cruises ranged from 650 to 2200 n.m. in cumulative distance travelled, and from 4 to 16 days. Temperature ranged from 16.8 to 30.1^{o}C over latitudes from 2 - 40^{o}S, and longitudes 148 - 170^{o}E.

B. SATELLITE DATA

The temperature data is obtained by high resolution radiometers in the infra-red ranges. Three data sources were used:

(1) GOSSTCOMP (Global Operational Sea Surface Temperature Computation) charts, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Earth Satellite Service, Washington D.C. 20233, USA, a NOAA product;

.../(2) NWS (National

(2) NWS (National Weather Service) charts, NMC/Marine Products Branch, World Weather Building, 5200 Auth Road, Camp Springs, MD. 20233 USA; (a NOAA product), and

(3) GMS (Geostationary Meteorological Satellite) reports, a product of the Meteorological Satellite Centre, Tokyo, Japan.

Examples of the form in which the satellite data is received are given in Figs. 1 to 3.

(1) GOSSTCOMP

The SST data is given as 1°C contours on Mercator projection maps. The maps used here are obtained at weekly periods. The date on the chart is the date on which the chart was created; the data depicted are primarily from the previous day. Claimed accuracy before averaging and plotting is generally better than 1° root-mean-square with coincident ship and buoy observations, with 8 km resolution. (Pichel and Banks, 1982). The original target area scanned ranges from 36 x 43 km to 36 x 81 km depending on satellite zenith angle, with target centres spaced approximately every 25 km.

On the maps 14 mm represents 10° of latitude at 30°S, and 12½ mm represents 10° of longitude. See Figs. 1(a), 1(b) for examples.

(2) NWS

The SST data is given as 1°C contours on maps. The maps used here are obtained at weekly intervals. Two scales are available, a Mercator projection world map covering 60°N to 60°S, and a polar projection of the Antarctic region, including Australia. On the world map 17½ mm represents 20° of latitude at 30°S, and 15 mm represents 10° of longitude. On the Antarctic map 36 mm represents 20° of latitude from 20 - 40°S and 30 mm represents 10° of latitude at 30°S. Claimed accuracy is not known. See Figs. 2(a), 2(b) for examples.

.../(3) GMS

(3) GMS

GMS data are published as monthly reports. The SST are given to 0.1°C for 1° x 1° lat-long squares, for a ten day average for days 1-10, 11-20 and 21-30 for each month. Claimed accuracy is not known. See Fig. 3 for an example of data. The SST are estimated from a histogram of data observed in each 1° latitude/longitude area assuming the higher temperature part corresponding to the sea-surface follows a Gaussian distribution. Cloud cover analyses are also given in the reports.

Time Availability of Satellite Data

The GOSSTCOMP and NWS products used in this memorandum are usually available at RANRL within 11 days after the end of an analysis period. Holdups occasionally occur when one analysis period may be received out of sequence several weeks later.

The GMS product is not available at RANRL until five months after the analysis month. Whether this is due to analysis or administrative delays is not known.

As discussed in the introduction, SST values are also available on a daily basis, and can therefore be used in real-time analyses.

.../5. METHOD OF

5. METHOD OF OBTAINING SATELLITE DATA CORRESPONDING TO A CRUISE

For GOSSTCOMP and NWS, the satellite SST were obtained for each cruise by plotting main way points of the cruise track directly onto the satellite SST maps. SST were taken where the ship track crossed the $1^{\circ}C$ contours, with some estimations e.g. at start and end points of cruises. This procedure was also followed for GMS, with some interpolation and averaging using the four SST values about the track when the track did not pass directly through given values. In some cases where the result of interpolation was not clear, the upper and lower value about the track were both plotted to show the possible range of the track value. For example see Fig. 9(a), 9(b).

Because of the large map scales, smoothing of the ship track occurs and errors of position of the whole degree contours are introduced but these appear to be within the resolution of the data as presented on the maps.

The data on the GOSSTCOMP and GMS charts were taken as representing the values for the days of the cruise which occurred in the seven days prior to the chart date.

.../6. PRE-DISCUSSION OF

6. PRE-DISCUSSION OF DATA AND METHOD OF COMPARISON

(a) The GOSSTCOMP and NWS charts used in this analysis are available at weekly intervals. The date on a chart is the date on which it was created, data depicted being primarily from the previous day. In this memorandum the chart data is taken as representing the values for the days of the cruise which occurred in the seven days ending at the chart date.

(b) If features change rapidly in the seven day period the ship and satellite data sets may not correspond. Correspondences found may occur by coincidence or if the features in an area change slowly.

(c) Some charts are based on scant information and the values for the previous period may be re-used.

(d) Since the ship data is continuous in time but for GOSSTCOMP and NWS one day's satellite data is here used to represent seven days, satellite data for points on the cruise track near the starts and ends of analysis periods will show changes in value corresponding to changes over the full period of seven days and not one day. Large changes from one period to another may appear on the plots of temperature versus ship track as bogus fronts or features. These must be allowed for. A similar problem will be met for the GMS data where the values given are averages over a ten day period.

(e) Ship thermographs measure "bulk" temperature, whereas satellites measure "skin" temperature from the top 0.05 mm of the sea-surface. Satellite SST usually have a negative bias with respect to ship SST (Pichel and Banks, 1982).

(f) The analysis in this memorandum is therefore far from an ideal method of compariso of sat te derived SST with sea-truth values, but as will be se , some meaningful results appear to be obtainable.

.../8. RESULTS OF COMPARISONS

7. RESULTS OF COMPARISONS AND DISCUSSION OF DATA

On the following pages are presented tables I to V giving some results of comparisons between satellite SST with ship SST for the five cruises examined. Cruise tracks are shown in Figs. 4 to 7, and SST versus cumulative ship distance are shown in Figs. 8 to 12. GMS data was not on hand for cruises SP 1/83 and SP 2/83, (more than six months after the cruises).

After the tables some discussion is given for each cruise concerning information not covered by the tables e.g. whether or not features in the ship SST were seen in the satellite SST.

NOTE: The positive bias in the tables refers to the percentage of cruise track for which the satellite SST values were higher than the ship values.

The five cruises covered approximately 7650 n.m. in 52 whole or part days over the period 29 September 1982 to 30 January 1983, with temperatures ranging from 16.8 to 30.1°C. Cruises ranged from 650 to 2200 nautical miles in cumulative distance travelled, and from 4 to 16 days. The latitude covered is 2 - 40°S, and longitude 148 - 170°E.

A. TABLES OF SOME RESULTS OF COMPARISONS

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	80	70	25
1 - 2°C	20	25	20
2 - 3°C	-	5	10
> 3°C	-	-	20
Unknown	-	-	25
Maxm. difference	-1.8°C to +1.3°C	-1.3°C to +2.1°C	0°C to 5.1°C
Positive bias	37%	52%	100%
Ship SST range	23.3 - 30.1°C		

Low variability area
Open ocean cruise starting and finishing among islands
Distance: 2200 n.m. Time: 16 days (29 Sep - 14 Oct 1982)

TABLE 1. Comparison of satellite with ship SST for Cruise SP10/82

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	95	77	-
1 - 2°C	4.5	20	1
2 - 3°C	0.5	3	35
> 3°C	-	-	64 *
Unknown	-	-	- **
Maxm. difference	-2.1°C to +0.9°C	-0.5°C to 2.9°C	+1.9°C to +4.9°C
Positive bias	35%	85%	100%
Ship SST range	17.1 - 23.1°C		

* (3-4 is 54%)
** (4-5 is 10%)

Low to moderate variability area
Open ocean cruise starting and finishing at a land mass
Distance: 2100 n.m. Time: 12 days (16-27 Oct 1982)

TABLE II. Comparison of satellite with ship SST for cruise SP11/82

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	46	59	14
1 - 2°C	32	20	16
2 - 3°C	13	7	4
> 3°C	9	14	4
Unknown	-	-	62
Maxm. difference	-2.3°C to +4.8°C	-1.2°C to +5.0°C	-4.1°C to +1.9°C
Positive bias	25%	61%	(67%)
Ship SST range	17.6 - 26.0°C		

High variability area
Within 60 n.m. of land for 90% of cruise
Distance: 1400 n.m. Time: 9 days (1-9 Dec 1982)

TABLE III. Comparisons of satellite with ship SST for Cruise SP12/82

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	76	71	
1 - 2°C	17	22	
2 - 3°C	7	7	
> 3°C	-	-	
Unknown	-	-	
Maxm. difference	-1.9°C to +3.0°C	-1.8°C to +3.0°C	
Positive bias	28%	61%	
Ship SST range	21.1 - 26.5°C		

High variability area
About 90% of cruise is within 60 n.m. of land
Distance: 1300 n.m. Time: 11 days (16-26 Jan 1983)

TABLE IV. Comparisons of satellite with ship SST for Cruise SP 1/83

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	71	61	
1 - 2°C	26	36	
2 - 3°C	3	3	
> 3°C	-	-	
Unknown	-	-	
Maxm. difference	-1.6 to +2.9°C	-1.6°C to +2.9°C	
Positive bias	38%	38%	
Ship SST range	16.8 - 24.6°C		

Moderate variability area
About one-third of cruise is within 60 n.m. of land
Distance: 650 n.m. Time: 4 days (27-30 Jan 1983)

TABLE V. Comparisons of satellite with ship SST for Cruise SP 2/83

B. DISCUSSION OF DATA FOR EACH CRUISE

Cruise SP10/82

Cruise Description.

The cruise track is shown in Fig. 4. This is essentially an open ocean cruise, distance approximately 2200 n.m., starting and finishing among islands.

Time: 29 Sep - 14 Oct 1982.

Figs. 8(a), 8(b), 8(c) show SST versus cumulative ship distance.

Ship SST Main Features.

SST lie within 28 - 30°C for the first 1300 n.m. falling by more than 6°C in the next 800 km to 23½°C, causing a marked change of slope after 1300 n.m. to strongly negative from roughly horizontal. Features occur at 550 n.m., 1000 n.m., 1200 n.m., 1300 n.m. and 1750 n.m. No sharp fluctuations are seen, so from the ship SST the area traversed may be classified as an area of low variability.

GOSSTCOMP

Data is available for periods ending 5, 12, 19 October.

SST lie within 1°C of ship SST on the average with a worst difference of approximately 2°C at 1750 n.m. The overall trends are well followed but mesoscale features are not. Some structure is seen before 1000 n.m., after 1300 n.m., and before 1750 n.m. which may correspond to the ship features displaced in time (and therefore distance) by the averaging procedure. Real changes of up to 1°C over less than 100-200 n.m. are averaged out and not seen. Broader scale features e.g. those about 1200-1300 n.m. are roughly represented by changes in slope. Lower SST are apparently given near land masses (-1°C). The change of slope around 1300 n.m. from Fig 8(b) to Fig. 8(c) is fairly well defined.

NOTE: The GOSSTCOMP maps for periods ending 5 and 12 October both indicate no information received for seven days.

NWS

Data is available for periods ending 3, 10, 17 October.

.../SST are within

SST are within $\pm$ 1°C after 400 n.m. but are 2°C greater before this, a different analysis period. The change of slope around 1300 n.m. is very well defined but to this point the slope is only grossly in agreement, showing none of the changes in direction of the ship data. Apart from the change in slope no real features are seen. There is an apparent jump in SST after 1800 n.m. caused by the change from one analysis period to another.

GMS

Data is available for period 1-10, 11-20 October.

No data is available within about 30 n.m. of the land masses. The feature at 550 n.m. is well shown, with about 40 n.m. displacement but following this SST are overestimated by 2°C for 300 n.m., becoming within 1°C for about 450 n.m. then departing drastically from the SST by 4°C for 500 n.m. Except at one point of equality, SST is always higher than ship SST.

Remarks

The GOSSTCOMP data is surprisingly good considering that no information was available for up to seven days. NWS and GOSSTCOMP differ by 2°C initially and less than or equal to 1°C elsewhere. GOSSTCOMP and NWS show average trends but cannot be used to detect fronts and features. The GMS data is highly erratic over the cruise. GOSSTCOMP is the best SST indicator for this cruise.

<u>Cruise SP11/82</u>

Cruise Description. The cruise track is shown in Fig. 4. This is an open ocean cruise starting and finishing at a land mass, of track distance 2100 n.m. One point is crossed three times in a period of 2½ days. Time: 16-27 October 1982. Figs. 9(a), 9(b), 9(c) show SST versus cumulative ship distance.

.../Ship SST Main

Ship SST Main Features

SST range over the cruise from 23°C to 17°C more or less decreasing by 4°C over the first half of the cruise, remaining on an average of 19°C for 500 n.m., followed by 250 n.m. of SST about 20°C. Many features occur involving fluctuations of 0.5 - 1°C about the smoothed SST over distances of 30 n.m., with larger scale features also, e.g. in the first 250 n.m. there is a constant SST of 21.5°C for 90 n.m. bounded by sharp changes of slope (more than 1.8°C in 40 n.m.). The ship SST show the area traversed to be of <u>low to moderate variability</u>.

GOSSTCOMP

Data is available for period ending 19, 26 October, 2 November.

SST Lie within 1°C or better of the ship SST over the entire cruise except for one 40 n.m. interval about 200 n.m. before the end of the cruise where they are 1 - 2°C underestimated at a higher temperature feature. The highly smoothed ship SST are closely followed by GOSSTCOMP except for a 250 n.m. interval towards the end of the cruise where GOSSTCOMP is parallel to the smoothed ship SST but lower by 0.5 - 1°C. The only feature shown is the sharp change of slope at the end of the cruise. Real changes of up to 2°C are not seen.

NWS

Data is available for period ending 17, 24, 31 October.

The SST are within 1°C of the smoothed ship SST except for the last 90 n.m. of the cruise near land when the sharp change of slope is not seen and SST are overestimated by up to 3°C. Peak temperatures often tend to be followed and NWS SST is greater than ship data for about 85% of the cruise. NWS does tend to show the high temperature feature 200 n.m. from the end of the cruise, but no other features are seen. The overall curve is in reasonable agreement with the trend of the smoothed ship SST.

GMS

Data is available for period 10-20, 21-31 October.

.../The GMS curve

The GMS curve is always 2 to 3.5°C higher than ship SST. When allowance for this difference is made the GMS curve tends to be similar to the NWS curve, but shows the slope change at the end of the cruise better than NWS.

Remarks

GOSSTCOMP and NWS are within 1°C of each other and ship SST for about 80 - 85% of the cruise. They often tend to envelope the ship SST. GMS is a poor temperature indicator for this cruise, overestimating SST by more than 2°C at all times, up to 5°C. Mesoscale features involving temperature differences of 1°C over 120 n.m. are not seen.

Cruise SP12/82

Cruise Description. The cruise track is shown in Fig. 5. This cruise is from Sydney to north of Fraser Island, returning via Cato Island, roughly 1400 n.m. long and is mostly less than 60 n.m. from land, except for 180 n.m. in an area of high variability. The track between 29° and 30° is traversed three times, the second and third passes being 'back to back' and five days after the first.
Time: 1-9 December 1982. Figs. 10(a), 10(b) show SST versus cumulative ship distance.

Ship SST Main Features

A sharp front occurs at 220 n.m. and what may be essentially the same feature is also seen about 300 n.m. from the end of the cruise, when the traverse between 29° and 30°S is repeated five days later. Many other fronts and major and minor features occur giving fluctuations of 0.5 to 1.5°C about the smoothed SST. SST ranges from 18.5 to 26°C. The ship SST show the area traversed to be of high variability.

GOSSTCOMP

Data is available for the periods ending 7th and 12th December.

The SST show a front at the start of the track which is displaced by 160 n.m. from the ship feature. SST are overestimated for 150 n.m. by up to 3.5°C in this region. SST is within 2°C of ship SST for the remainder of the cruise except about 300 n.m. from the end of the cruise when a undetected sharp front leads to deviations again up to 3.5°C over an interval of about 40 n.m. (If the GOSSTCOMP curve were displaced

about 150 n.m. to the right it would fit the grossly smoothed ship SST quite well but this may only be coincidence). The slope changes in the GOSSTCOMP curve do follow the trend of the ship data but show no real features.

NWS

Data is available for the periods ending 5th and 11th of December.

SST are greater than ship SST for the first half of the cruise, which is close to land, tending to follow peak temperatures. The front at 220 n.m. is not shown leading to SST being overestimated by up to 4°C, after which SST are within 1 to 1.5°C of the grossly smoothed ship SST except 300 n.m. from the end when the undetected front leads to overestimations of up to 4°C for about 50 n.m. Average trends are well followed after the first 220 n.m.

GMS

Data is available for the period 1-10 December.

No data is available for two-thirds of the cruise. Data is available roughly 60 n.m. from land. The available data is within 1 to 1.5°C of grossly smoothed ship SST and tends to follow average trends. However the final data point underestimates ship SST by about 4°C. An interpolation using surrounding squares gives a better result.

Remarks

This cruise represents a tough test of the satellite data and both GOSSTCOMP and NWS do surprisingly well, although showing no features. GOSSTCOMP and NWS are within less than 1.5°C of each other for the entire cruise. The three traverses of the same section between 29° to 30°S show the front to be in the same area after a five day period and this may indicate that conditions did not change very much, allowing favourable results. SST for traverse BC is also similar to that of JK. GMS is not a good indicator in this area, being unable to give values near land masses.

.../Cruise SP 1/83

Cruise SP 1/83

Cruise Description. The cruise track is shown in Fig. 6. The cruise is from Sydney to Brisbane and return, mostly within 60 n.m. of the coast, track distance 1300 n.m. Several areas are traversed more than once.
Time: 16-26 January 1983. Figs 11(a), 11(b) show SST versus cumulative ship distance.

Ship SST Main Features

Several sharp fronts are seen in the SST. Some of these are "mirrors" caused by re-tracing the track previously followed. The ship SST show the area traversed to be of high variability.

GOSSTCOMP

Data is available for the periods ending 25 January, 2nd February.

SST is within 2.5°C or better of ship SST for the cruise. Average trends are well followed except towards the last 240 n.m. of the cruise when an apparent front (in the ship data) is not seen, and SST are underestimated by up to 1.5°C. No features are seen. Interpolation between whole degree values does suggest the real slope change seen in the first 60 n.m.

NWS

Data is available for periods ending 16, 23 January, 2 February.

The NWS curve follows the overall trend of the ship data except at the most northerly point where overestimation occurs, showing a peak not present in ship SST. Temperature values are within 2.5°C or better of ship SST. No real features are seen.

GMS

GMS data for January and February has not yet been received as of late August.

.../Remarks

Remarks

GOSSTCOMP and NWS are within 1°C of each other for the northward leg of the cruise (680 n.m.) and within about 1.5°C for the remainder where they tend to envelope the ship SST. GOSSTCOMP and NWS perform well in this high variability area with maximum deviation from ship SST being within 2.5°C for all but 30 n.m. of the cruise.

Cruise SP 2/83

Cruise Description. The cruise track is in Fig. 7. The cruise is from Sydney to Flinders Island in Bass Strait, about 650 n.m. long, about one-third being within 60 n.m. of land.
Time: 27-30 January 1983. Fig 12 shows SST versus cumulative ship distance.

Ship SST Main Features

A sharp front is seen at the start of the cruise followed by roughly constant SST following which the temperature falls from 24.5°C to 17°C in 470 n.m. leading to a change in slope. Several features are seen also. The ship SST show the area traversed to be of moderate variability.

GOSSTCOMP-NWS

GOSSTCOMP
Data is available for the period ending 1 February.
NWS
Data is available for the period ending 30 January.

GOSSTCOMP and NWS are within less than 0.5°C of each other for the entire cruise. Both miss the front at the start of the cruise (near land) and both show the slope change seen in smoothed ship SST. In Bass Strait proper inside the 200 metre depth contour both overestimate SST by 1 to 1.5°C. Neither shows any real feature apart from the slope change. Within 30 n.m. of Sydney both overestimate SST by up to 3°C, missing the front close to land, otherwise they are 1 to 1.5°C or better within ship SST, following the average of ship SST.

GMS

GMS data for this period has not yet been received as of late August.

.../Remarks

Remarks

NWS and GOSSTCOMP are very nearly the same curve. Average trends are well followed but no features detected. A front within 30 n.m. of land is not seen.

8. OVERALL RESULTS OF COMPARISONS

Ability of Satellite Data to Discern Fronts and Features

The satellite data sources did not usually show any structure suggesting features. Average trends over 200-500 n.m. were well followed i.e. the slope of the highly smoothed ship data was well followed, including changes in slope caused by changes in ship direction. See for example figures 8 and 12 for SP10/82, SP 2/83. Features seen in GOSSTCOMP data generally correspond in some manner to real features but cannot be used as a reliable spatial indicator. NWS does not usually show features. GMS was erratic e.g. see Fig. 8(c).

Agreement of Absolute Satellite SST Values with Ship SST

GOSSTCOMP-NWS

GOSSTCOMP and NWS were usually within 2°C of ship SST for 80% of the cumulative ship distance travelled or better, and within about 1.5 - 2°C of each other for all cruises. For the two open ocean cruises SP10/82, SP11/82, GOSSTCOMP was within 2°C of ship SST for 99.5 - 100% of the cruises, and NWS within 2°C for 95 - 97%. Maximum departures between 4 - 5°C from ship SST were seen in SP12/82, a cruise in a high variability area on a portion of the track within 20 n.m. of the coast-line. This was the only cruise in which either GOSSTCOMP or NWS differed by greater than 3°C from ship SST, the percentage of cruise track being 9 and 14 respectively for a 1400 n.m. cruise. See Tables I to V for other results.

GMS

Data is available only for cruises SP10/82, SP11/82, SP12/82.

The GMS SST were often over 3°C greater than ship SST e.g. in Fig. 9 for SP11/82 the GMS values are over 2.5°C greater than ship SST for practically the entire cruise. Figs. 8 and 10 for SP10/82 and SP12/82 also show large deviations. GMS in Fig. 8 for SP10/82 departs drastically from ship SST towards the end of the cruise to give a spot difference of 5.1°C, and differences up to 4°C, after previously being within 0.5°C of ship SST. GMS appears to be unreliable as a data source for

.../absolute temperature

absolute temperatures, on the basis of the three cruises examined. Data for adjacent analysis periods cannot be related to each other in terms of absolute temperature without some external information. See Fig.8(c) (just after 1800 n.m. where absolute SST values show a large deviation from ship values in the analysis period 11-20 October). See Tables I to III for other results.

Temperature Bias

Bias here refers to the proportion of satellite SST higher or lower than the ship SST, with respect to the ship track. In Tables I to V positive bias refers to the percentage of cruise track for which the satellite SST are higher than ship SST.

GOSSTCOMP gave SST lower than ship SST for about two-thirds of each cruise track.

NWS gave SST greater than ship SST for about two-thirds of each cruise track.

GMS gave SST greater than ship SST for two-thirds to all of each cruise track. (Note: More recent GMS data use improved algorithms).

The biases of GOSSTCOMP and NWS support a tendency for them to envelope ship SST. See for example SP11/82 (Fig. 9). The extreme positive bias of GMS can possibly be used to determine upper limits for satellite SST. NWS often tends to follow peak temperatures e.g. see Fig 9(c), and Fig 10(a).

Note: Data for another cruise SP 7/83 showed only a 12% positive bias for NWS data. See the Appendix.

Satellite Performance in Areas of High Variability/Performance Near Land Masses and Islands

The two high variability cruises SP12/82, SP 1/83 are both within 60 n.m. of land for 90% of the cruise track. See Figs. 5 and 6. Major fronts were undetected but GOSSTCOMP and NWS SST were within 2^{o}C of ship SST for about 80% of the cruise track for SP12/82, and within 2^{o}C for better than 90% of SP 1/83, a very good result. The worst performance areas appear to be within 30 n.m. of land in SP12/82.

.../GMS does not

GMS does not appear to give values within 30 n.m. of land. (Thirty nautical miles may be the closest distance to land that the satellite sources can give useful data on SST before being affected by the different readings from the land).

Agreement of Satellite Data with Claimed Accuracy

GOSSTCOMP is the only satellite source for which figures are available. An accuracy of generally better than $1^{\circ}C$ root-mean-square compared with coincident ship and buoy observations is given (Pichel and Banks, 1982). For these five cruises the percentage of ship track within $2^{\circ}C$ were 100, 99.5, 78, 93 and 97. Percentage within $1^{\circ}C$ were 80, 95, 46, 76 and 71. (For a normal distribution 68.27% of values lie one standard deviation on either side of the mean value, 95.4% lie within two standard deviations, and 99.73% lie within three standard deviations). For these five cruises, in low to high variability areas, the claimed accuracy is well supported.

NWS is within $1^{\circ}C$ of ship SST for the percentages 70, 77, 59, 71, 61, and within $2^{\circ}C$ for the percentages 95, 97, 79, 93, and 97. NWS appears to be less accurate than GOSSTCOMP in the open ocean cruises of low variability with respect to $1^{\circ}C$ difference from ship SST, but only slightly less accurate with respect to a $2^{\circ}C$ difference. Generally the root-mean-square difference is probably better than $1^{\circ}C$ for these cruises.

GMS is within $1^{\circ}C$ for the three cruises SP10/82, SP11/82, SP12/82 for the percentages 33, 1, and 37. For $2^{\circ}C$ the percentages are 60, 1, and 79. For $3^{\circ}C$ the percentages are 73, 36, and 89. These figures apply to those parts of the cruise track for which GMS gives data. There is often a large positive bias in the GMS data, with differences over open ocean cruises of $3^{\circ}C$ and more, from ship SST. (Note: more recent GMS data are derived from improved algorithms).

9. CONCLUSIONS

On the basis of these five cruises GOSSTCOMP is the most reliable sea-surface temperature indicator, often closely following the graph of grossly smoothed ship values. See Figs. 9(a), 9(b), 9(c) for cruise SP11/82. NWS is comparable to GOSSTCOMP but shows fewer smaller scale trends, and is often not as close to ship SST in absolute value. See Figs. 8(a), 8(b), 8(c) for cruise SP10/82. NWS often seems to follow peak temperatures e.g. see Figs. 9(c) and 10(a) for cruises SP10/82, SP11/82. GMS is unreliable as a data source, often overestimating SST by 3°C and not being consistent from one analysis period to another. See Fig. 8(c) for cruise SP10/82.

Note: More recent GMS data use improved algorithms which may lessen the overestimation.

The satellite data sets cannot usually be used to detect fronts or features but large scale average trends are well shown, over distances of up to 20° in latitude (see Figs. 8(a), 8(b), 8(c) for cruise SP10/82) with spatial resolution of perhaps 200 - 300 nautical miles in areas of low to moderate variability.

On the average NWS can be used to give absolute values of SST within 2°C with probably better than 80% surety and within 1°C with better than 60% surety. GOSSTCOMP can be used to give absolute values of SST within 2°C with much better than 80% surety, and within 1°C from better than 46% surety to usually better than 70% surety.

On the basis of these five cruises it appears that absolute SST values found by GOSSTCOMP and NWS may be successfully used in real-time analyses, within the limits given above. Away from sharp fronts the smoothed gradients of sea-surface temperature given by satellite are usually in very good agreement with those found by ship, enabling the satellite data to complement other available data e.g. expendable bathythermograph, to draw good SST contours in an area. The real time satellite data which is available should therefore be very useful for NAS Nowra weekly analyses, especially when the comments made earlier on the method of comparison of ship and satellite SST used in this memorandum are considered.

APPENDIX

ADDITIONAL DATA

Some additional data became available after this memorandum had been prepared. See Tables VI, VII, VIII on pages 24 and 25.

Tables only are given for three other cruises; R.V. Sprightly cruise SP7/83 and RANRL cruise 30/82 on HMAS Kimbla, leg 1 and leg 2. Note that SST data for cruise 30/82 was obtained by expendable bathythermograph (XBT). The cruises were in latitudes 35°S to 47°S and longitudes 148°E to 153°30'E. A large part of cruise SP7/83 and leg 1 of RANRL 30/82 occurred in high winds and rough seas. Cruise tracks are snown in Figs 13 and 14.

NWS

The NWS bias below 35°S has reversed from the strongly positive values found earlier to very strongly negative, positive bias figures being 12, 35, and 17%, as opposed to the figures of 52, 85, 61, 61, and 38 given earlier. The figure of 38 was also for a cruise south of 35°S. There is also a tendency for a greater percentage of satellite values to be more than 1°C different from ship SST, however the figure of 80% surety given earlier for values within 2°C of ship SST is still true for these cruises.

The change of bias appears to be a real feature, possibly being due to the lower temperatures below 35°S or different algorithms used for these higher latitudes, and/or absorption coefficients.

GOSSTCOMP

Gosstcomp data also shows a tendency on cruise SP7/83 and leg 1 of RANRL 30/82 to be more than 1°C from ship SST than found earlier but the figure of 80% surety for values within 2°C of ship SST is still true. For leg 2 of cruise RANRL 30/82 better than 99% of values are within 2°C of ship SST, and 78% of values are within 1°C. Much of this cruise occurred during much calmer weather than did cruise SP7/83 and leg 1 of RANRL 30/82.

Remarks

For these more southerly latitudes the results of comparisons of ship and satellite temperature are largely as found for the cruises in latitudes 2°-35°S but the NWS bias appears to have reversed.

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	52	53	
1 - 2°C	18	22	
2 - 3°C	17	25	
> 3°C	13	< 0.5	
Unknown	-	-	
Maxm. difference	-3.7 to +1.9°C	-3.1 to +3.1°C	
Positive bias	18%	12%	
Ship SST range	16.7 - 22.7°C		

High variability area
Within 30 n.m. of land for 25% of cruise
Distance: 750 n.m. Time: 8 days (14-21 April 1983)

TABLE VI. Comparisons of satellite with ship SST for Cruise SP 7/83

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	66	65	
1 - 2°C	12	17	
2 - 3°C	12	13-15 *	
> 3°C	10*	3-5 *	
Maxm. difference	-4.9* to +2.0°C	-3.8*to +2.3°C	
Positive bias	35%	35%	
Ship SST range	14.3 - 24°C or 14.3 - 22.5°C*		

High variability area
Open ocean cruise starting near and finishing at a land mass
Distance: 900 n.m. Time: 7 days (16-22 April 1983)

TABLE VII. Comparisons of satellite with ship SST for Cruise RANRL 30/82, Leg 1. XBT Data.

* Two doubtful high temperature XBT values occurred in the data.

Temperature difference (ΔT) Ship and Satellite SST	Percentage of Satellite SST within ΔT of Ship SST		
	GOSSTCOMP	NWS	GMS
≤ 1°C	78	66	
1 - 2°C	21	18	
2 - 3°C	<1	5	
> 3°C	-	11	
Unknown	-	-	
Maxm. difference	-2.2 to +2.0°C	-3.7 to +1.7°C	
Positive bias	40%	17%	
Ship SST range	10.8 - 18.4°C		

Moderate to high variability area
Open ocean cruise starting and finishing at a land mass
Distance: 680 n.m. Time: 8 days (29 April - 6 May 1983)

TABLE VIII. Comparisons of satellite with ship SST
for Cruise RANRL 30/82, Leg 2.
XBT Data.

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Pichel, W.G. (1982) in a letter dated September 13, 1982 to users of GOSSTCOMP contour charts, subject - Implementation of Contour Chart Changes, United States Department of Commerce, National Oceanic and Atmospheric Administration, National Earth Satellite Service, Washington D.C. 20233.

Pichel, W.G. and Banks, B.A. (1982). Reliability of Operational Sea Surface Temperatures Derived from NOAA Satellite Infrared Data. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Earth Satellite Service, Washington D.C. 20233.

ACKNOWLEDGEMENTS

Thanks are due to the Division of Oceanography, CSIRO Marine Laboratories, for the sea-surface-temperature data obtained on cruises by R.V. Sprightly. Cruises SP10/82 and SP11/82 were part of the WESTROPAC program.

This memo was prepared for Dr. P.J. Mulhearn, Ocean Sciences Division RANRL as part of an ongoing ocean analysis in waters off Australia in support of work carried out by the Naval Air Station Nowra.

LIST OF FIGURES

Additional Data

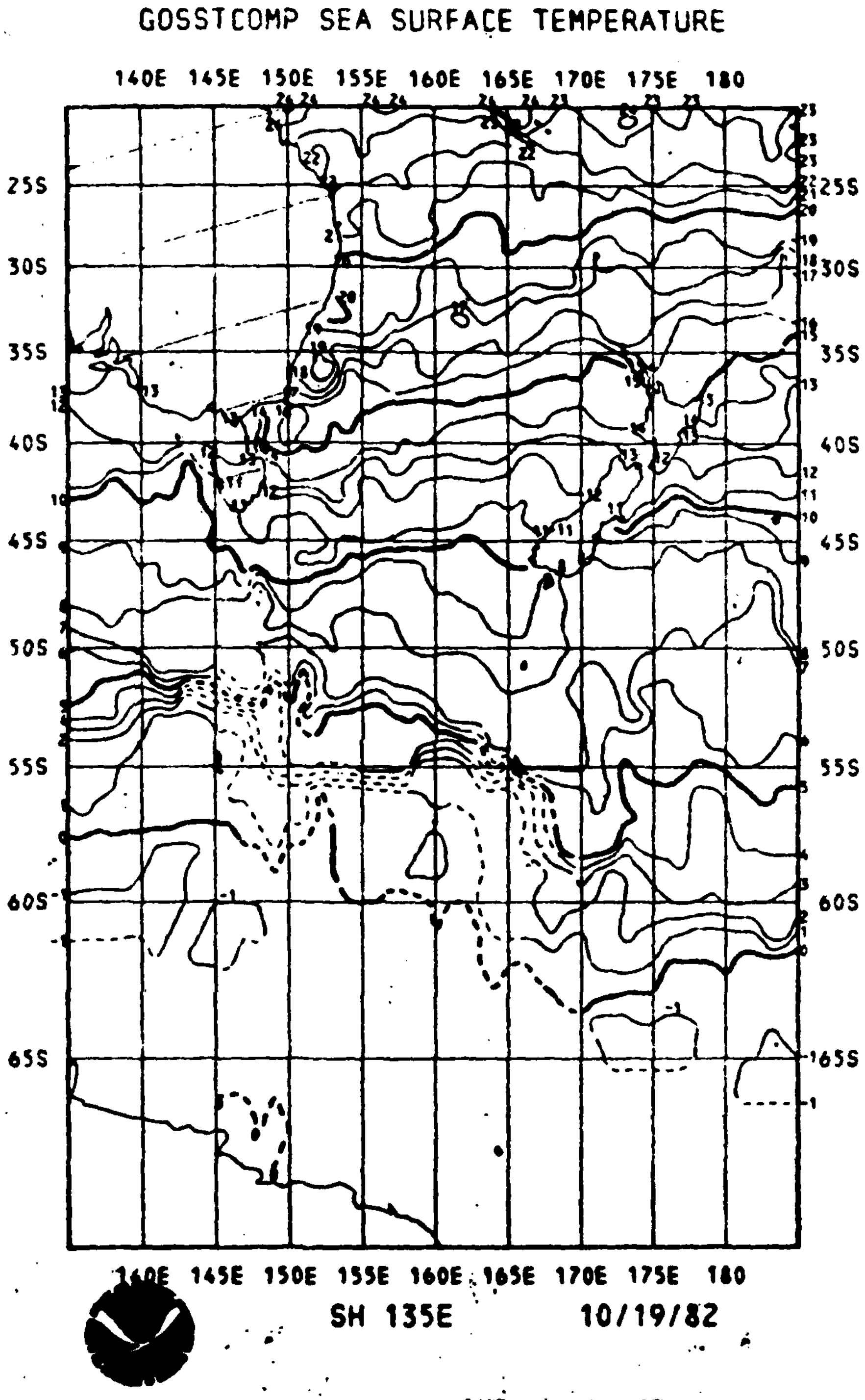

Fig.1(a). GOSSTCOMP Satellite SST Data.
Example 1.
A possible eddy pattern is located at
36°30'S, 152°30'E.

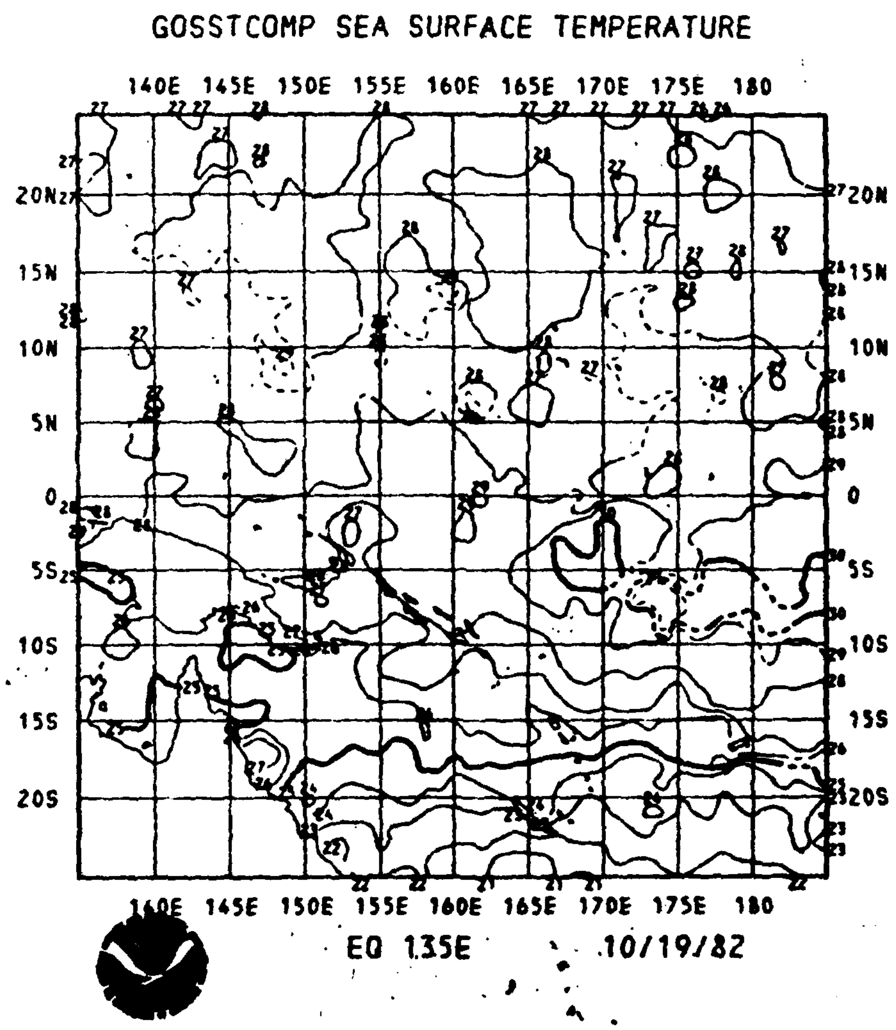

Fig. 1(b). GOSSTCOMP Satellite SST Data.
Example 2.

FIGURE 2(a)

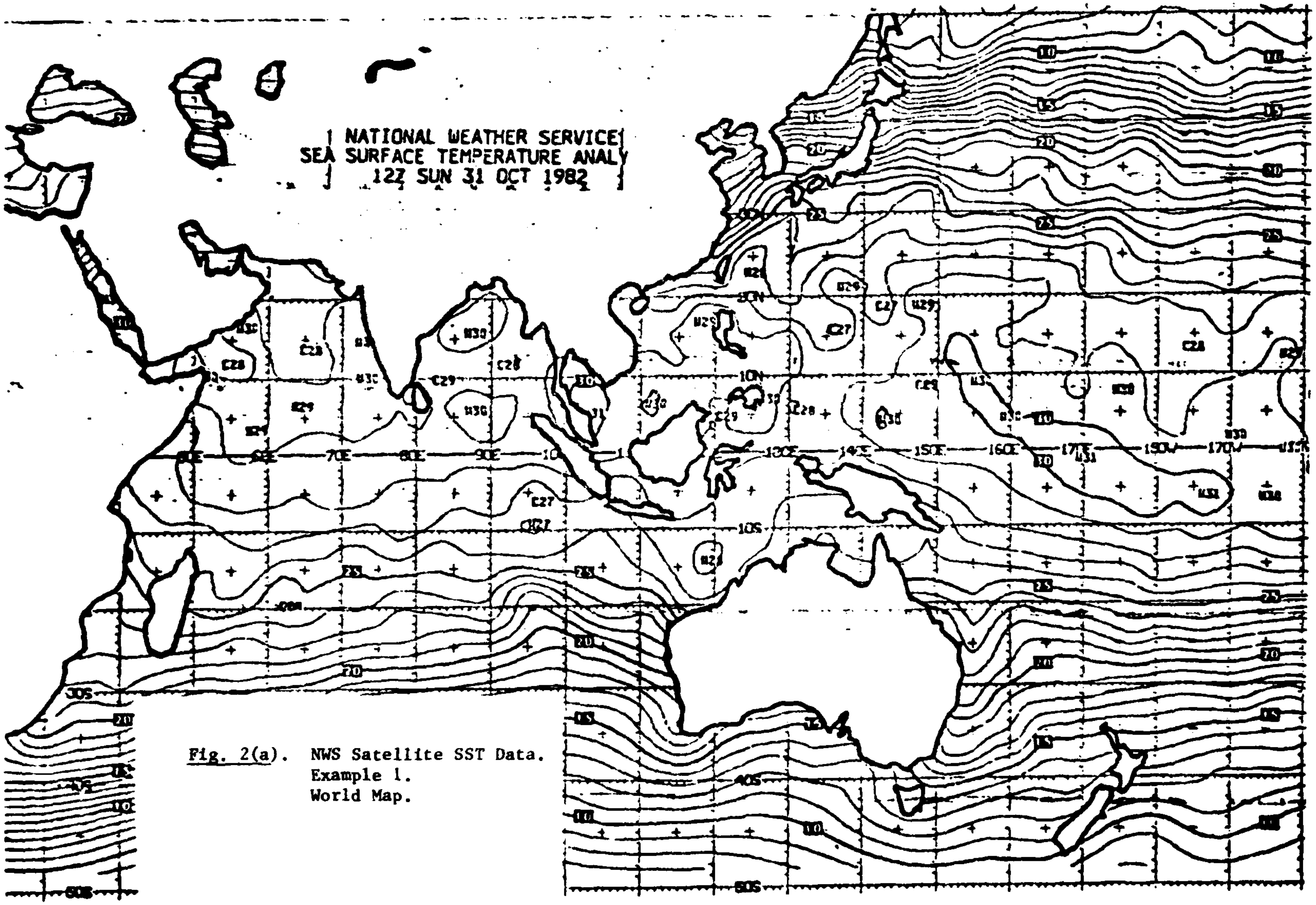

Fig. 2(a). NWS Satellite SST Data.
Example 1.
World Map.

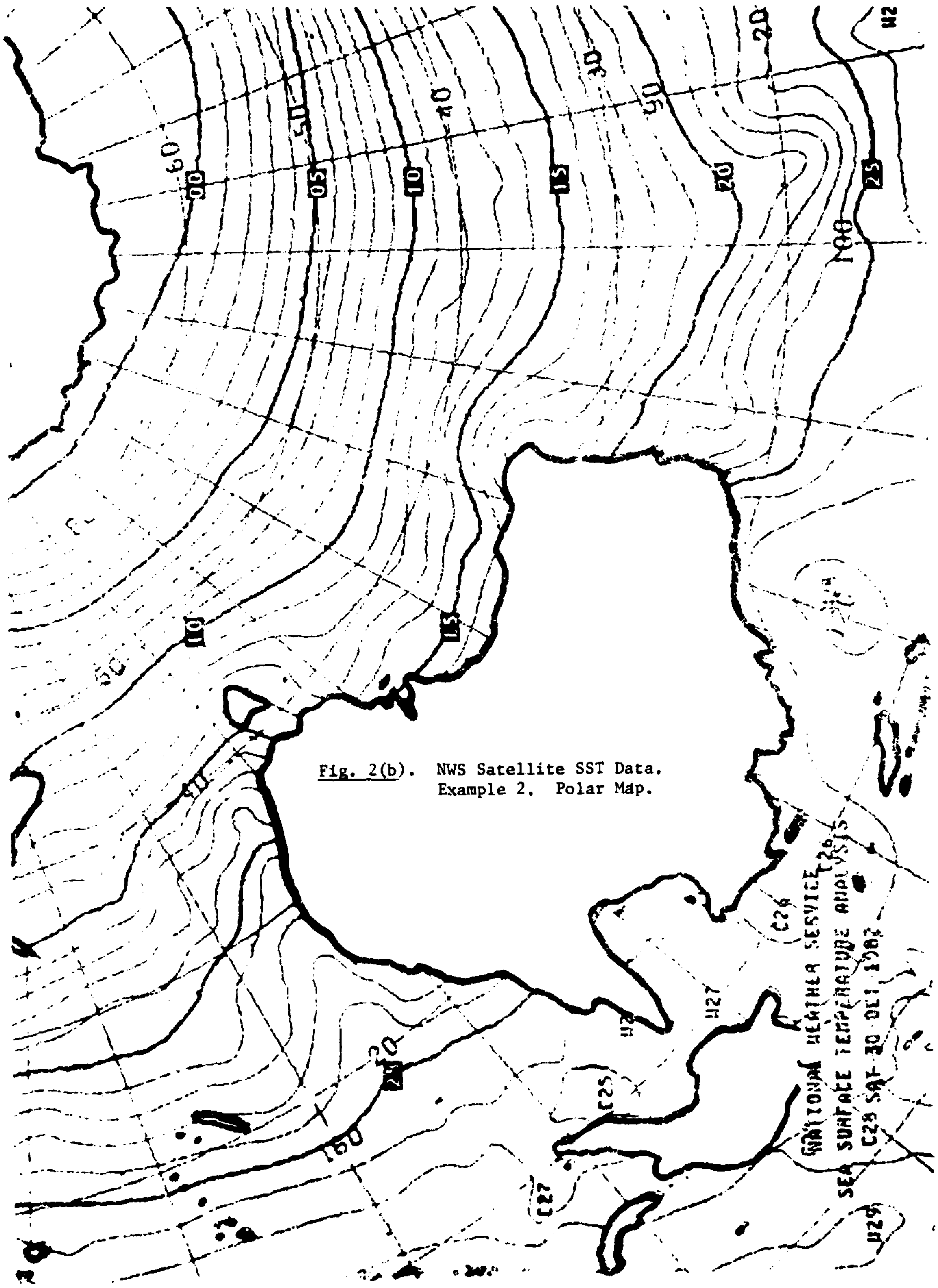

Fig. 2(b). NWS Satellite SST Data. Example 2. Polar Map.

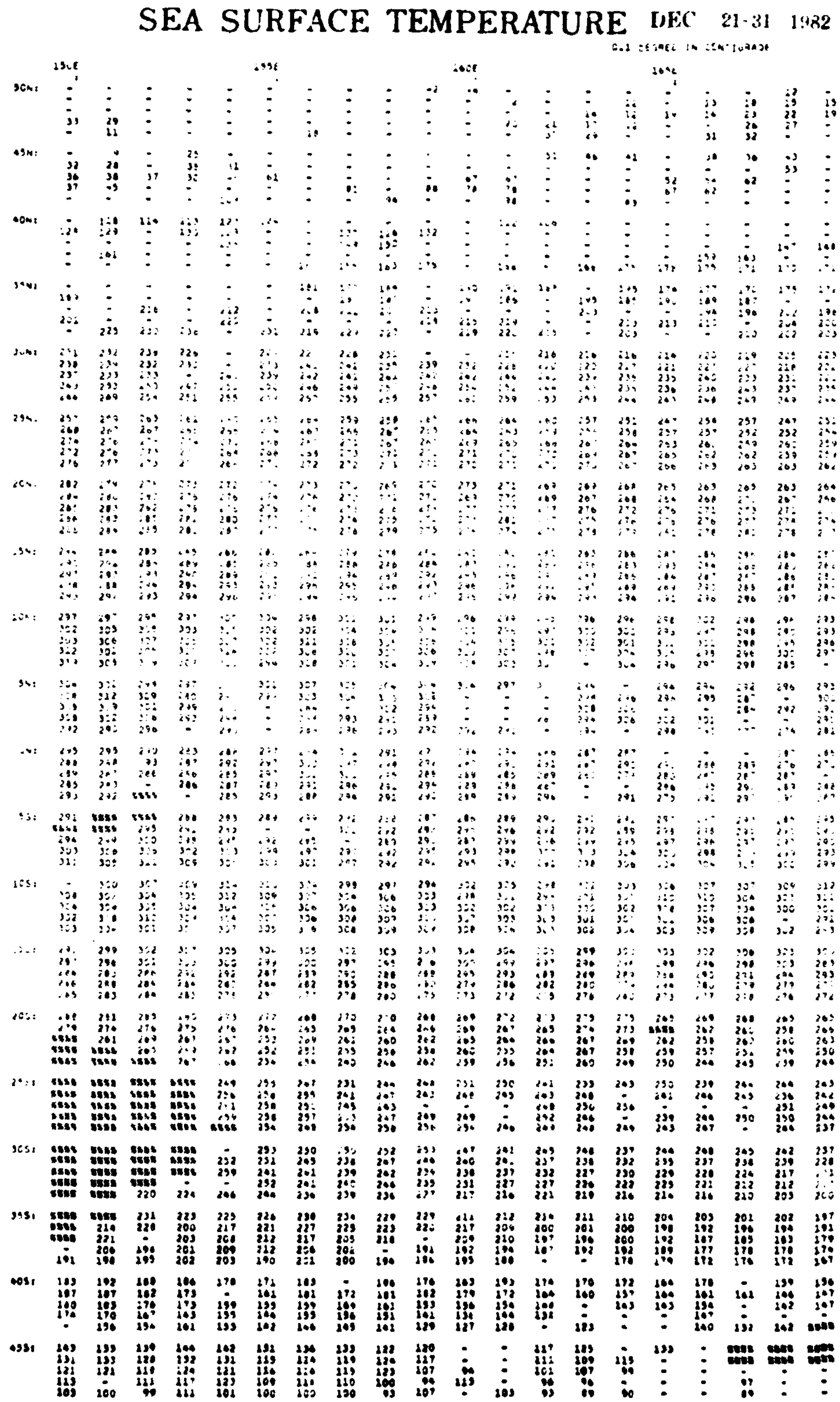

Fig. 3. Example of GMS SST satellite data.

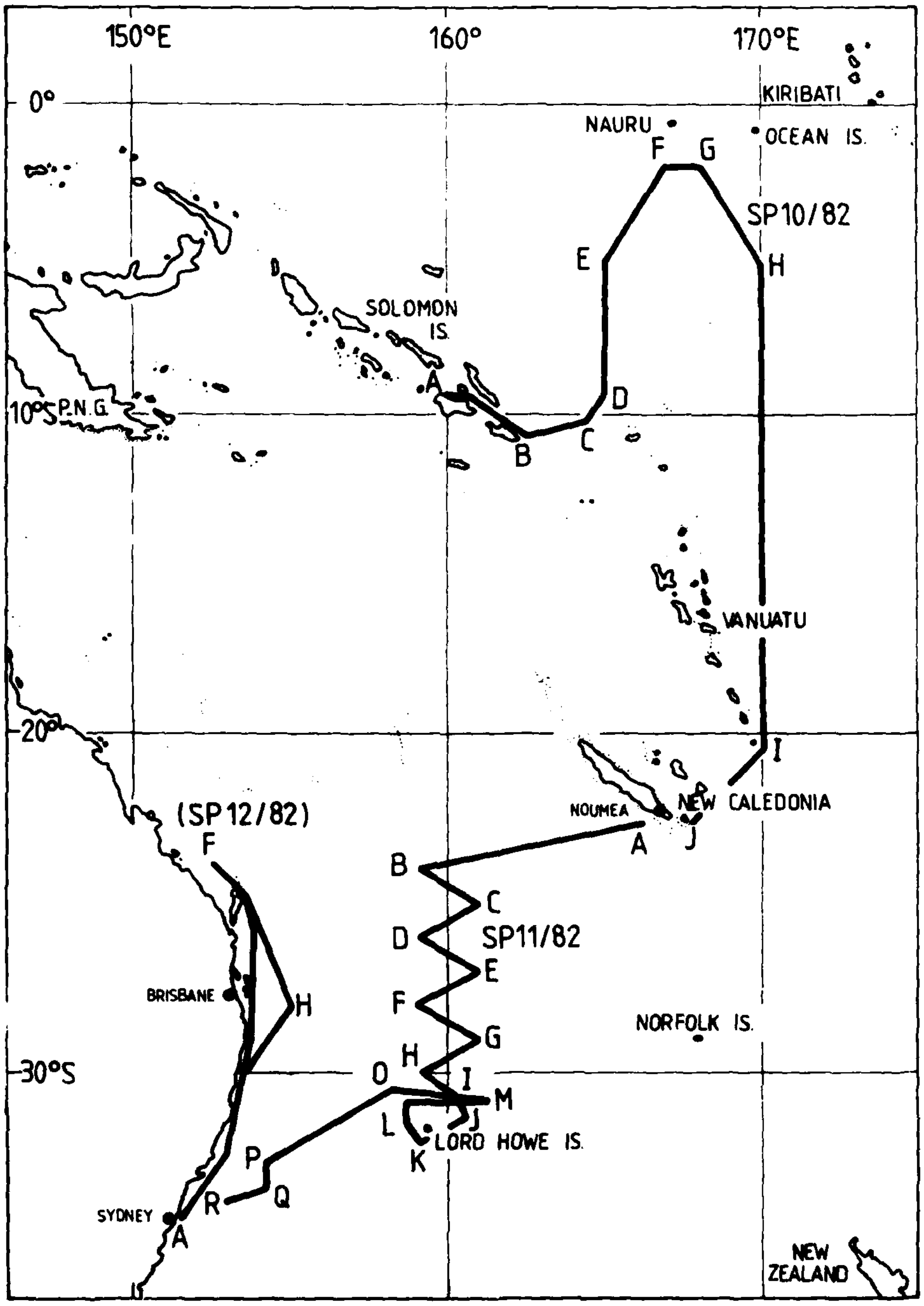

Fig. 4. Cruise track R.V. Sprightly SP10/82, SP11/82.
SP10/82 29 September–14 October 1982.
SP11/82 16–27 October 1982.

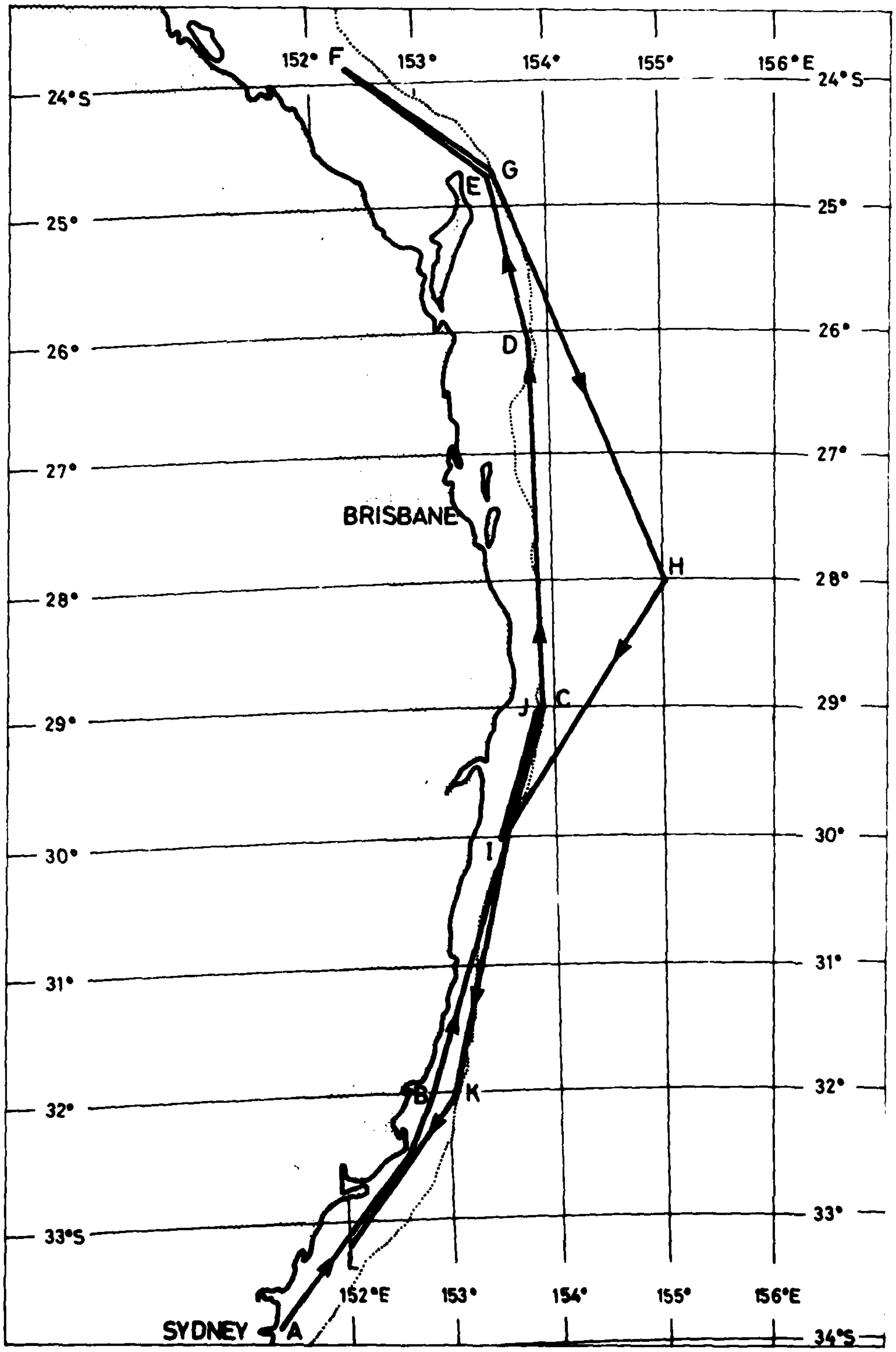

Fig. 5. Cruise track R.V. Sprightly SP12/82
1 - 9 December, 1982.

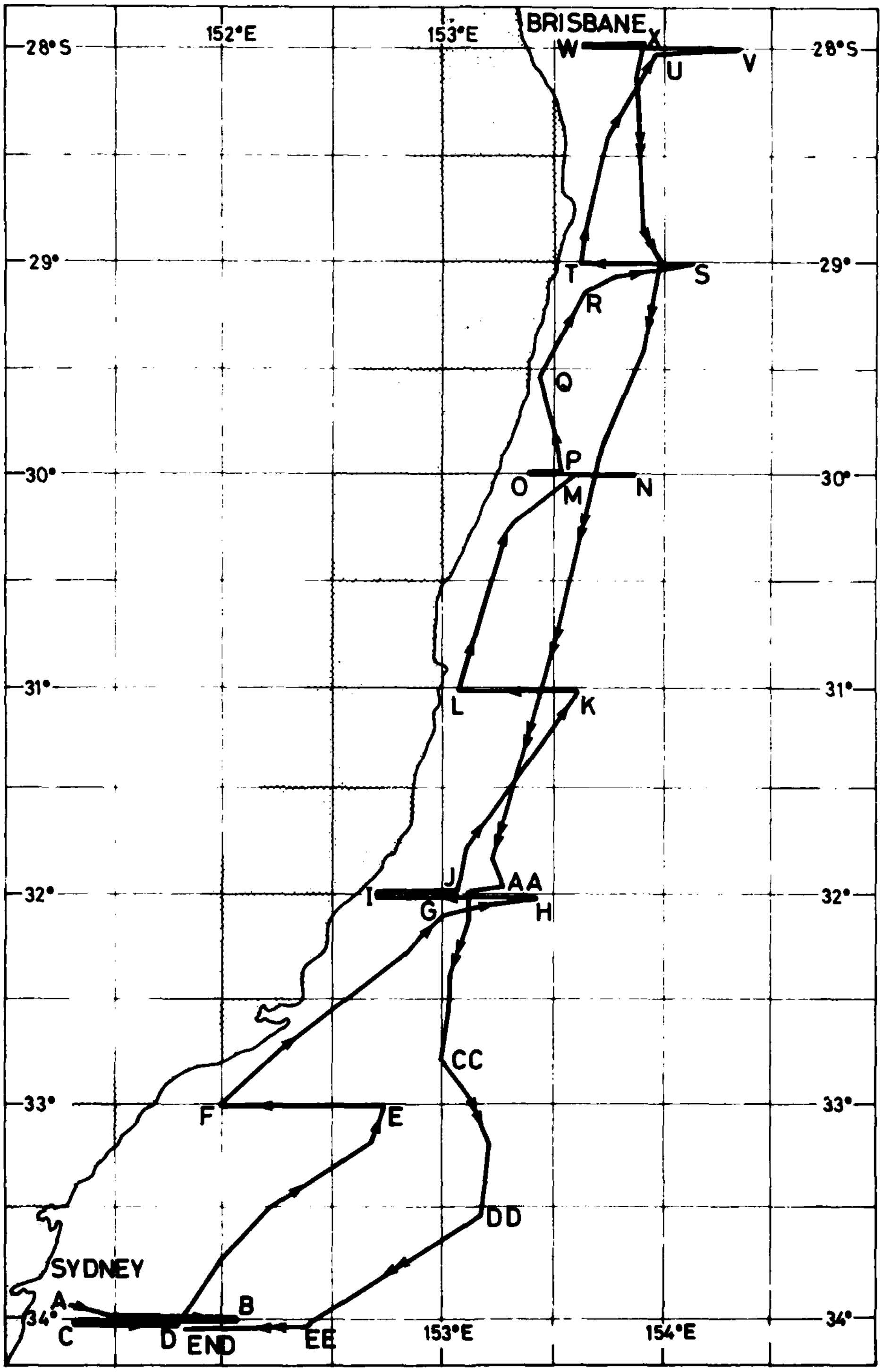

Fig. 6. Cruise track R.V. Sprightly SP1/83.
16 - 26 January, 1983.

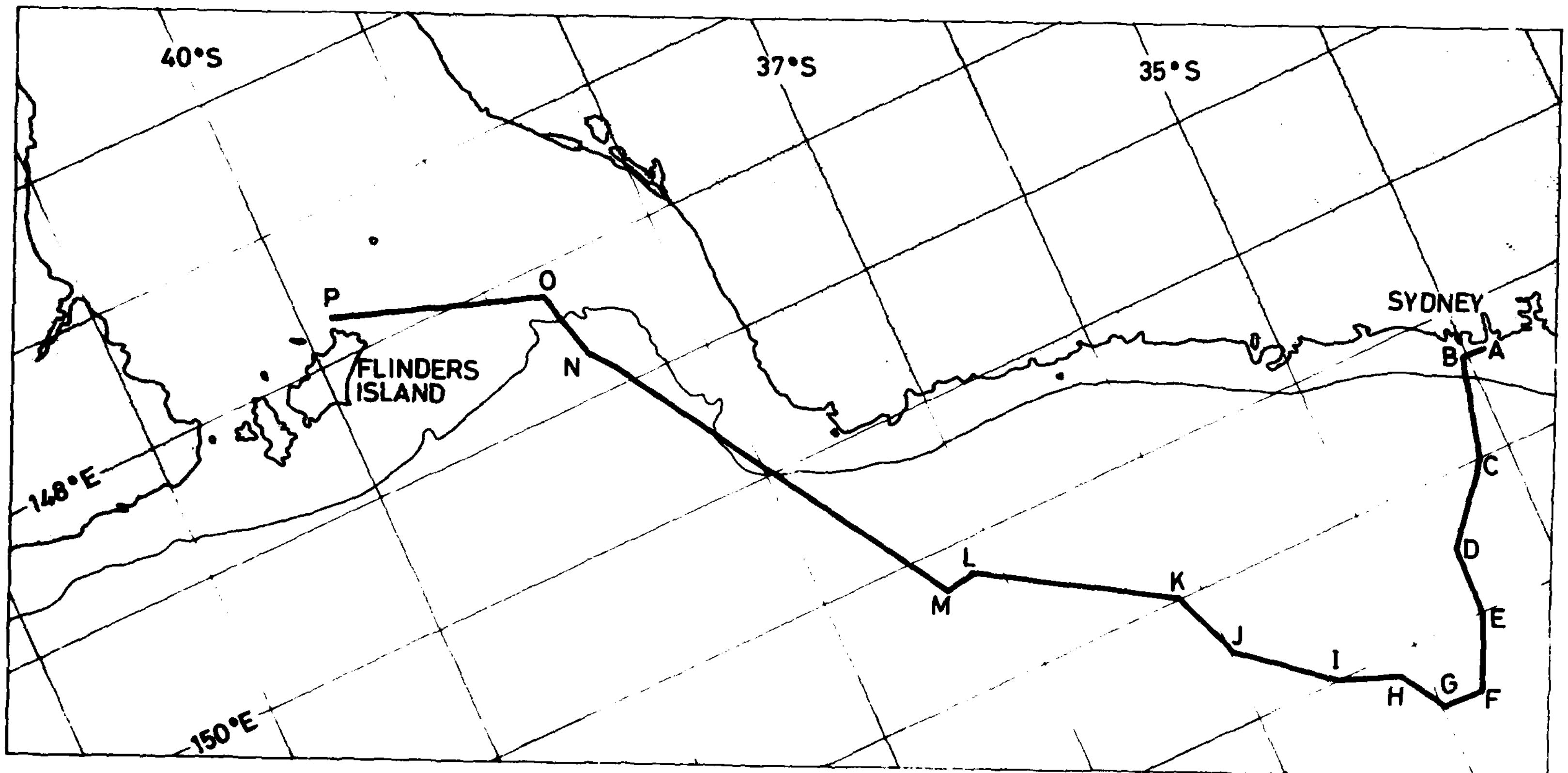

Fig. 7. Cruise track R.V. Sprightly SP2/83 27-30 January, 1983.

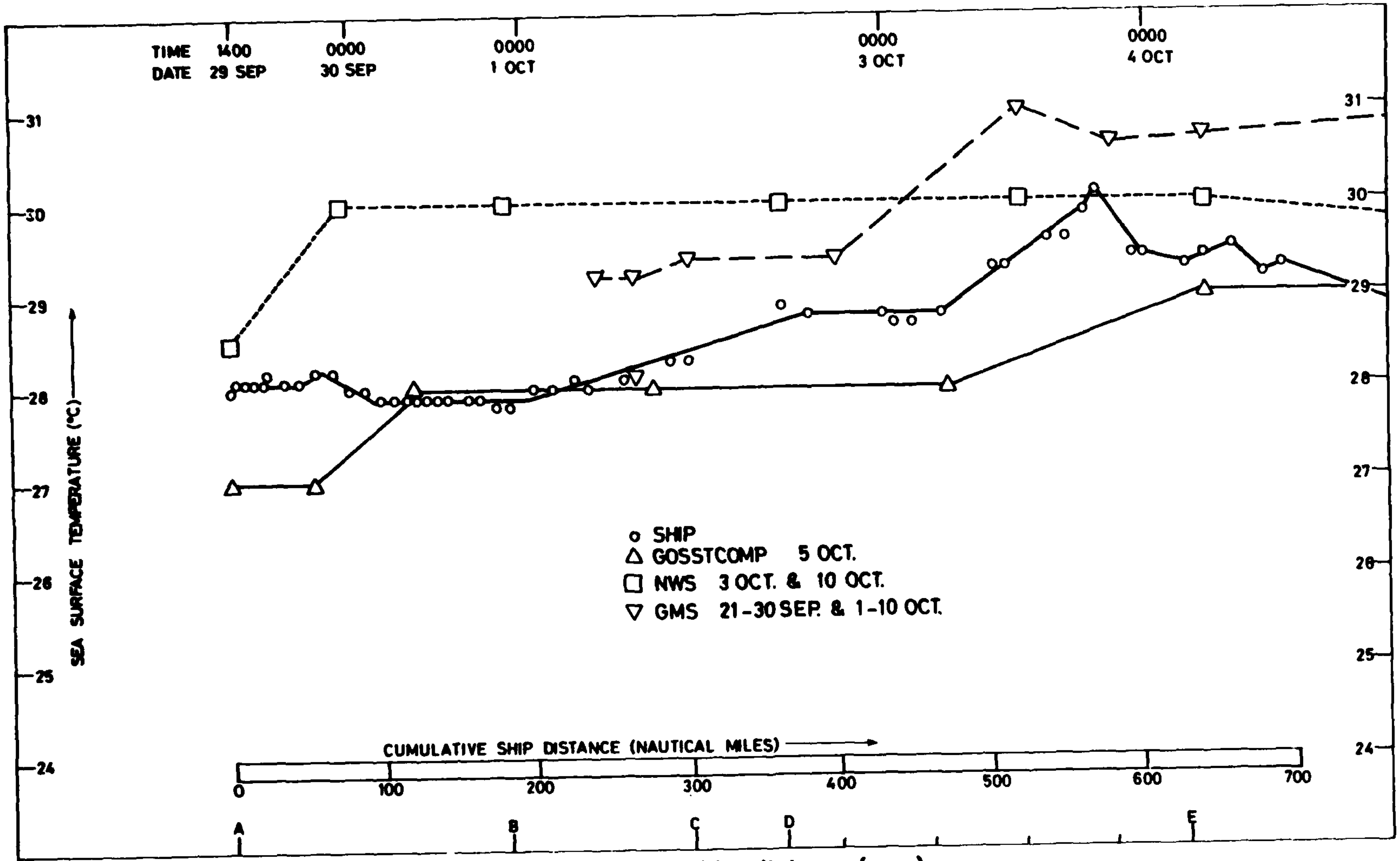

Fig. 8(a). Sea surface temperature(°C) vs cumulative ship distance(n.m.)
Cruise R.V. Sprightly SP10/82 29 September - 4 October 1983.

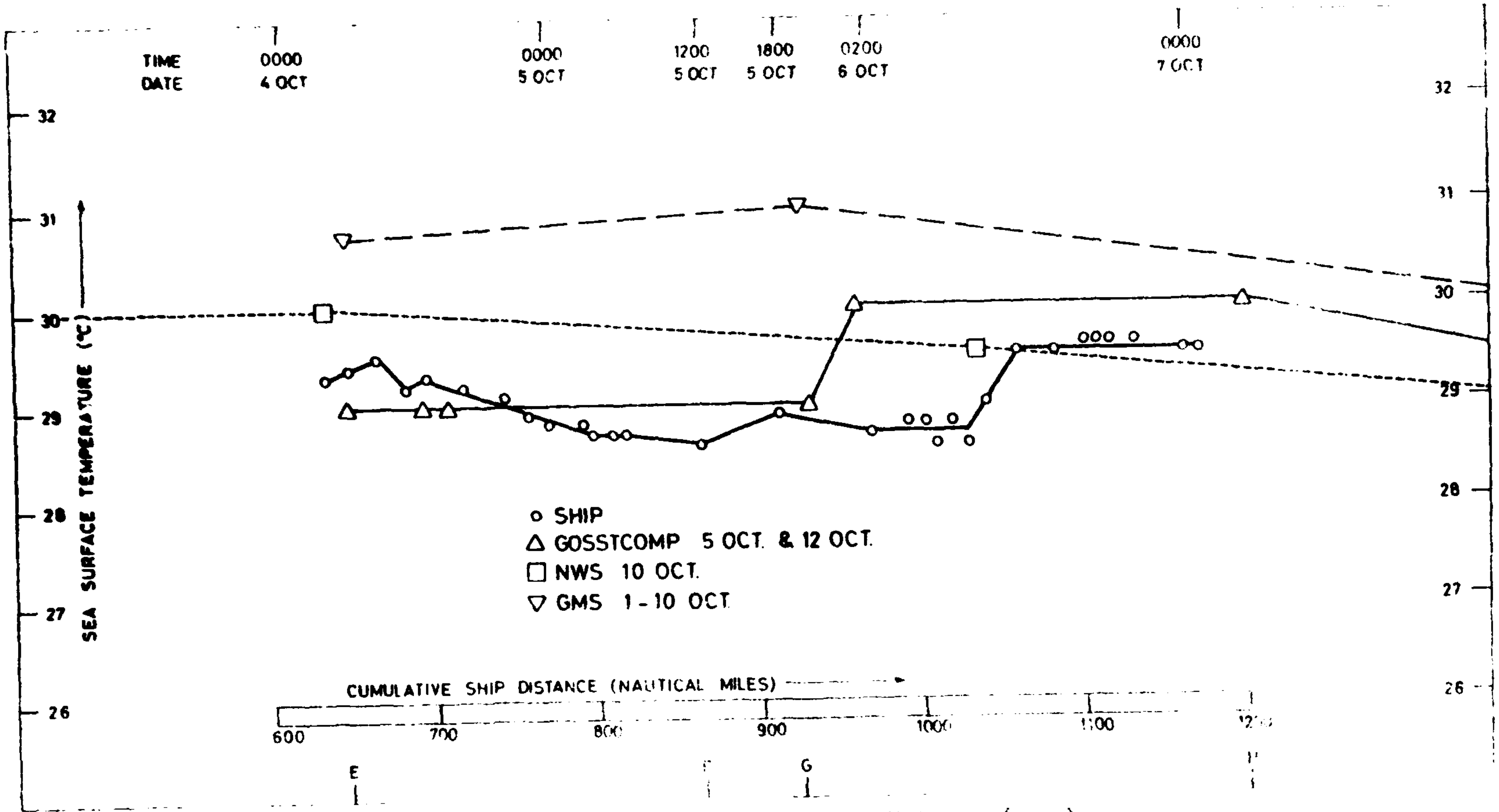

Fig. 8(b). Sea surface temperature (°C) vs cumulative ship distance (n.m.) Cruise R.V. Sprightly SP10/82 4 -7 October, 1982

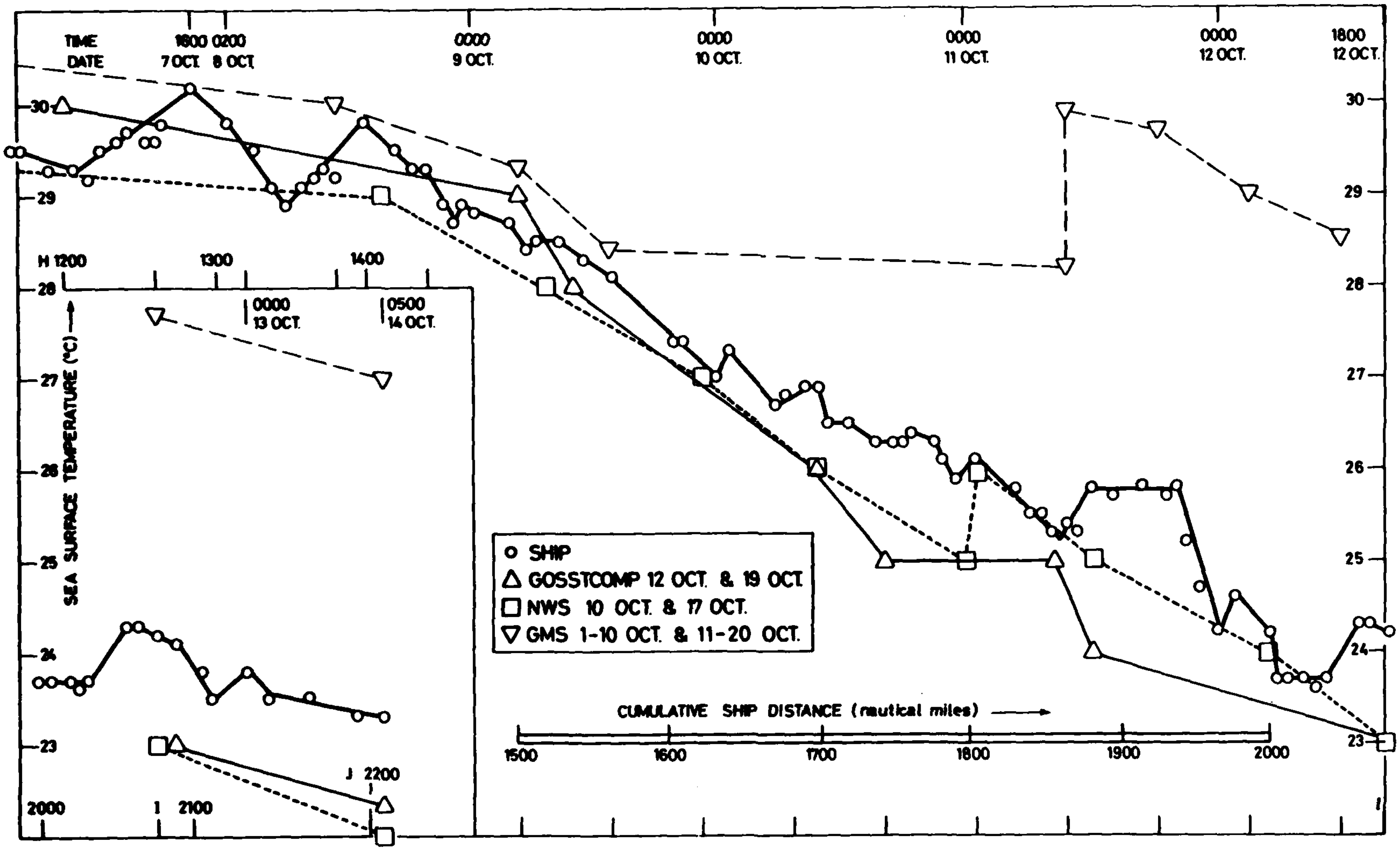

Fig. 8(c). Sea surface temperature (°C) vs cumulative ship distance (nm). Cruise R.V. Sprightly SP 10/82 7-14 October 1982. (Note:- Insert on left hand side is continuation of ship track.)

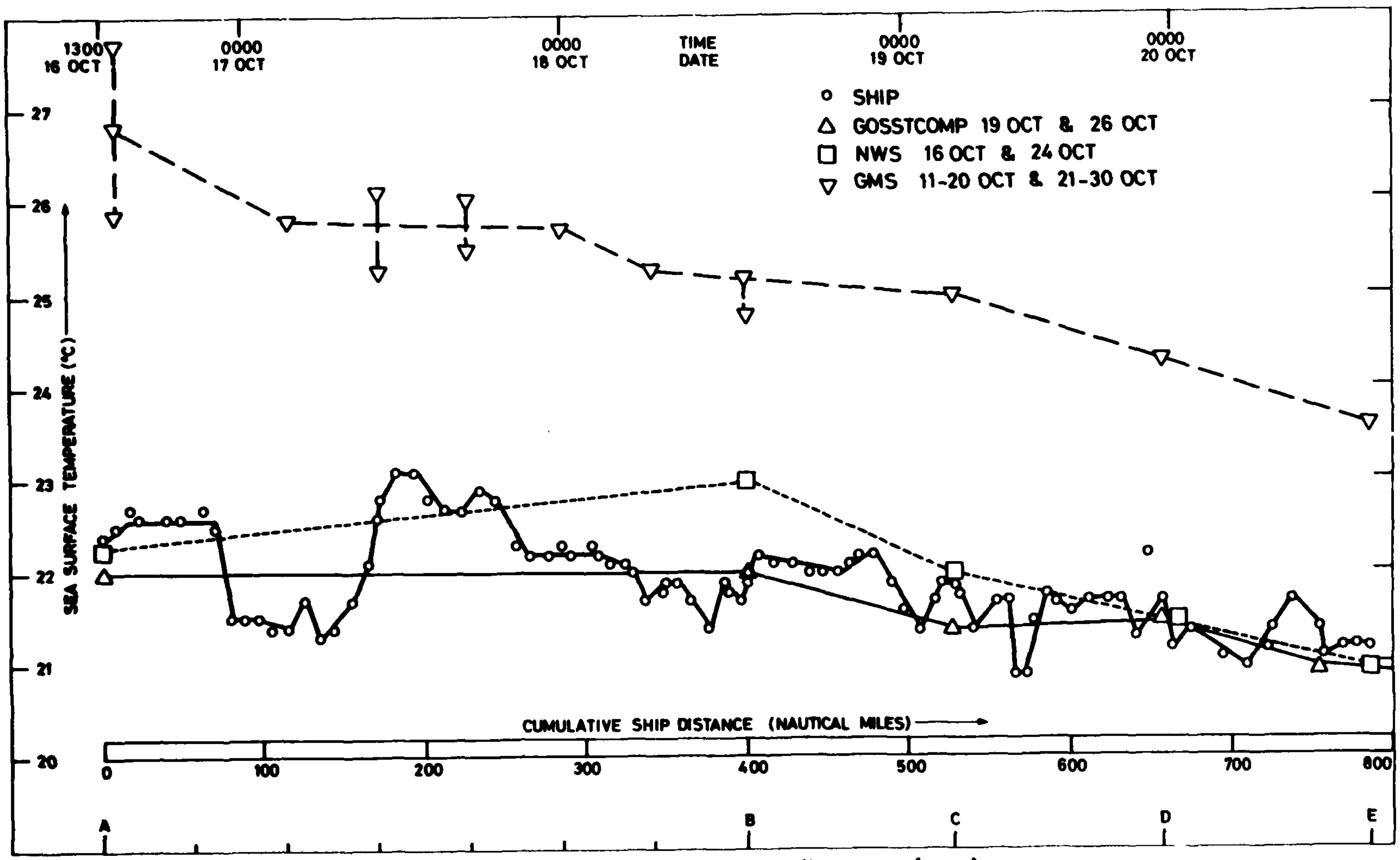

Fig. 9(a). Sea surface temperature (°C) vs cumulative ship distance (n.m.).
Cruise RV Sprightly SP11/82 16-21 October 1982.

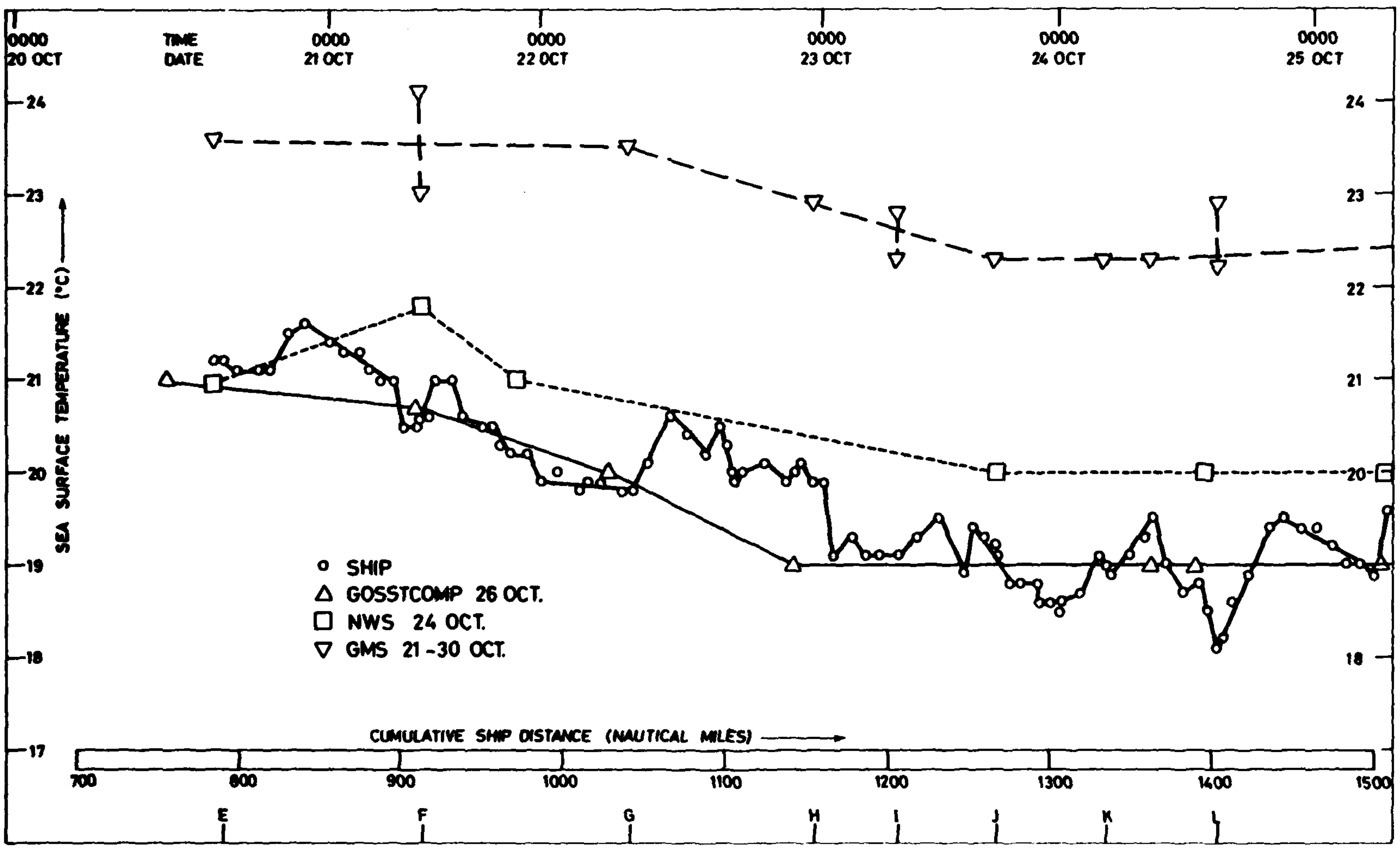

Fig. 9(b). Sea surface temperature (°C) vs cumulative ship distance (n.m.)
Cruise R.V. Sprightly SP11/82 20-25 October 1982.

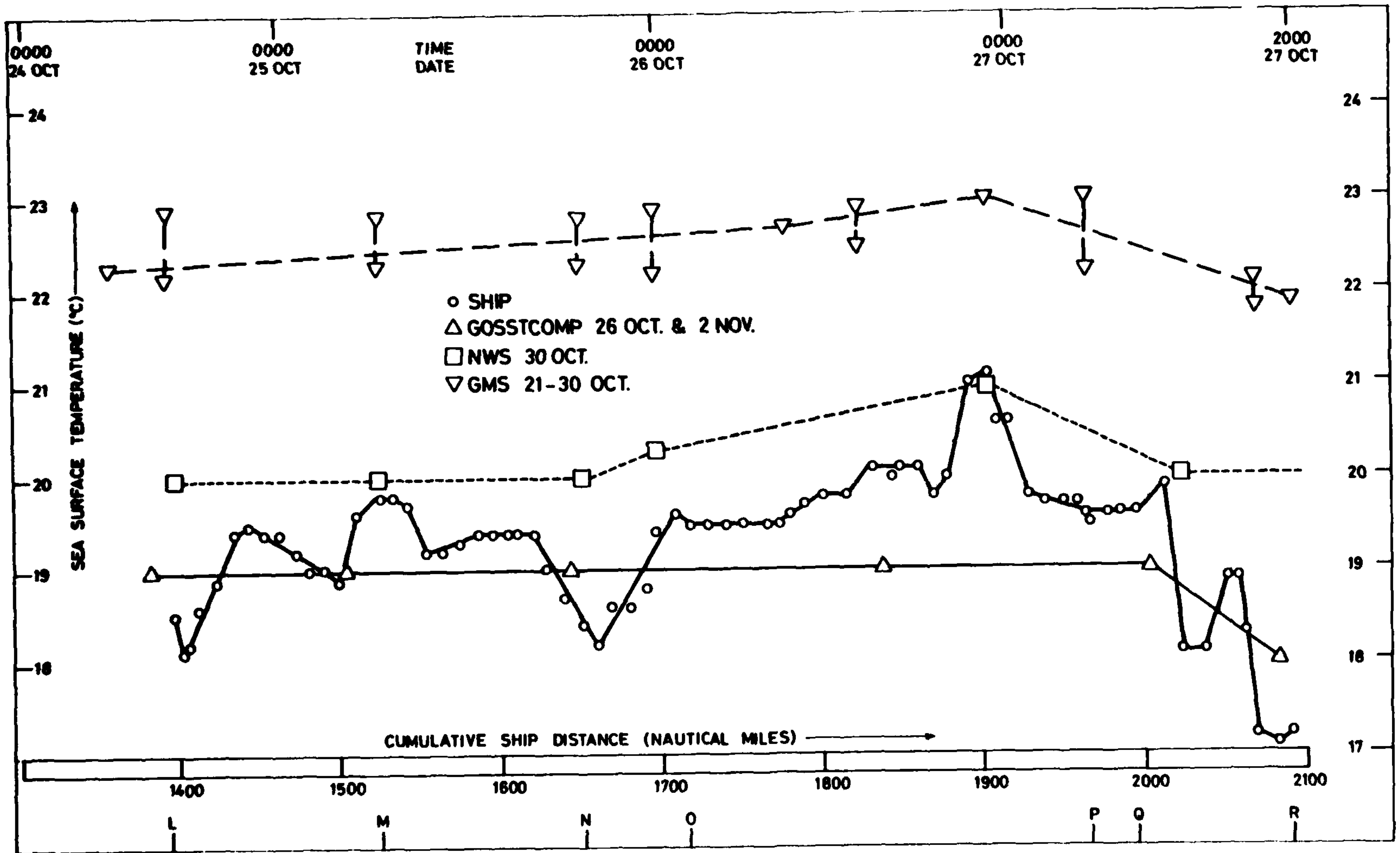

Fig. 9(c). Sea surface temperature (°C) vs cumulative ship distance (n.m.)
Cruise R.V. Sprightly SP11/82 24-27 October, 1982.

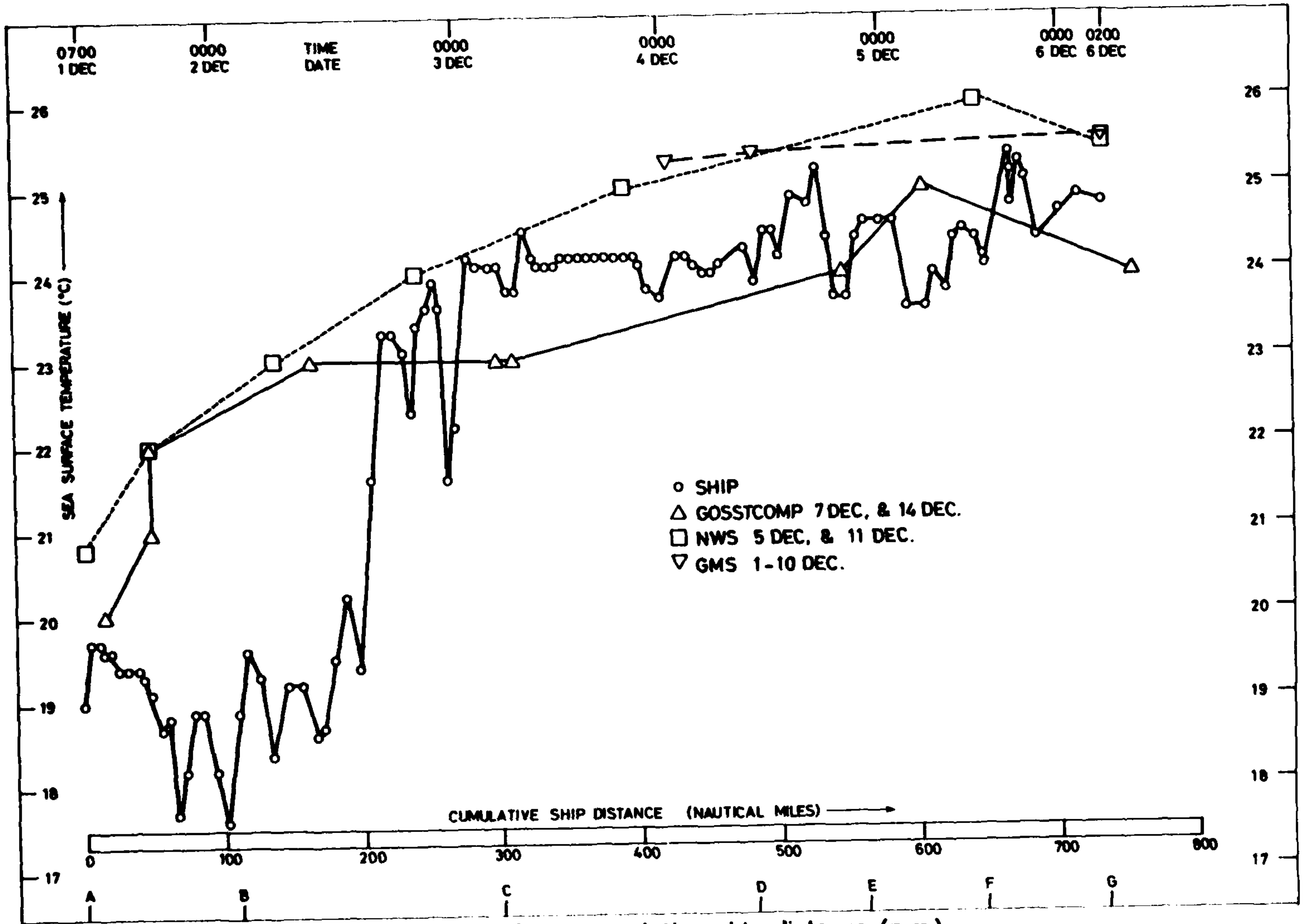

Fig. 10(a). Sea surface temperature (°C) vs cumulative ship distance (n.m.)
Cruise R.V. Sprightly SP12/82 1-6 December, 1982.

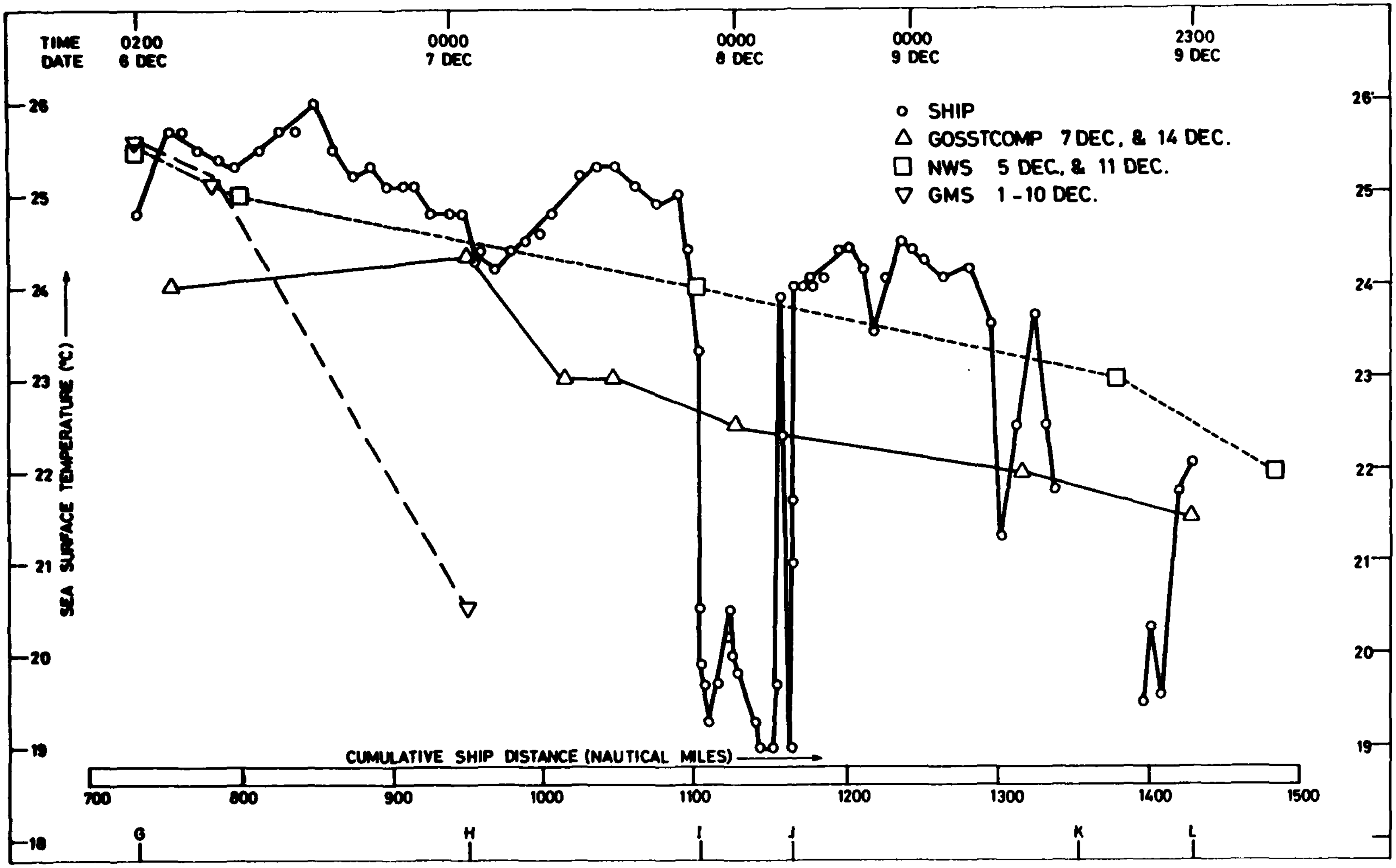

Fig. 10(b). Sea surface temperature (°C) vs cumulative ship distance (n.m.).
Cruise R.V. Sprightly SP12/82 6 - 9 December, 1982.

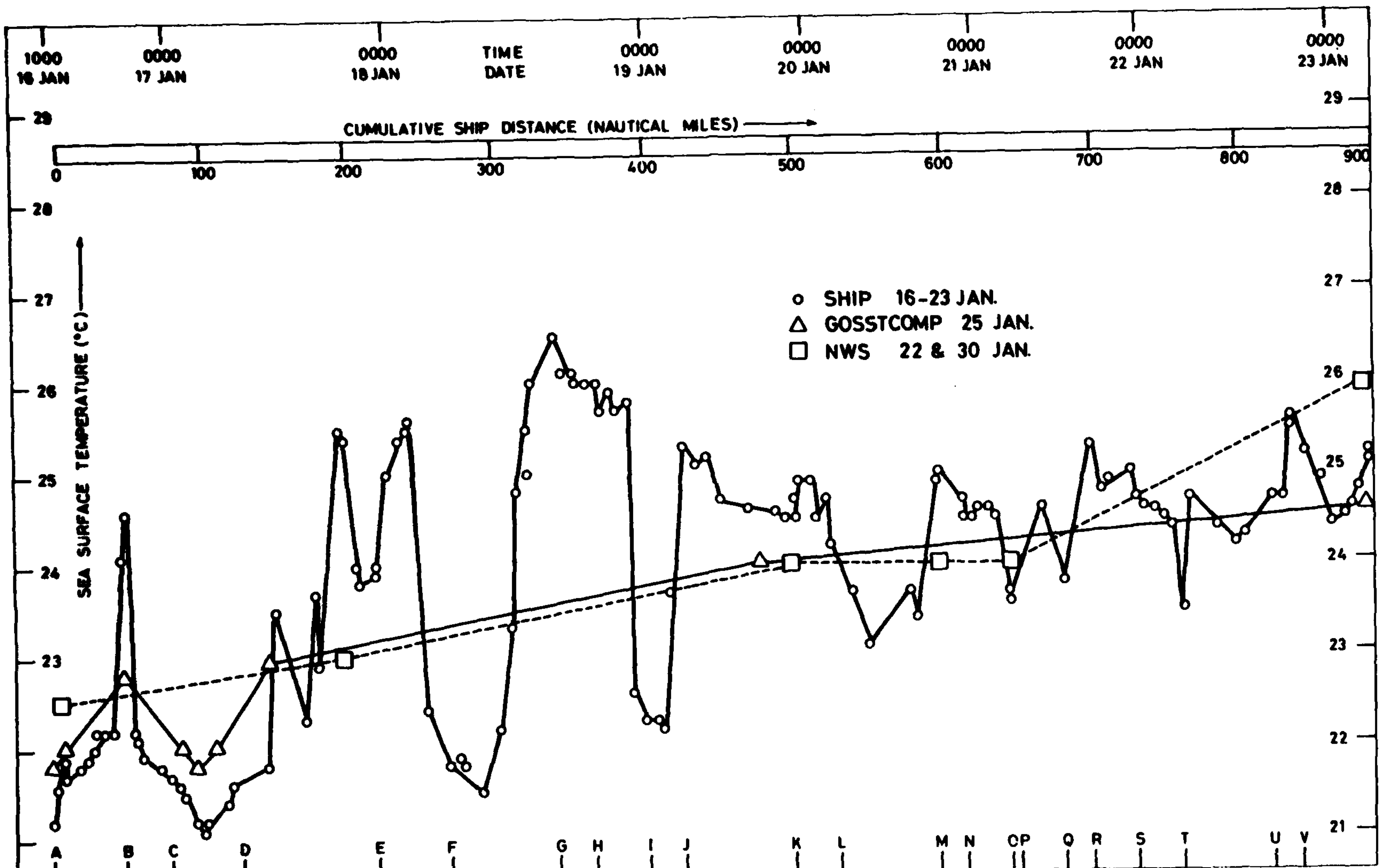

Fig. 11(a). Sea surface temperature (°C) vs cumulative ship distance (n.m.).
Cruise R.V. Sprightly SP1/83 16-23 January 1983.

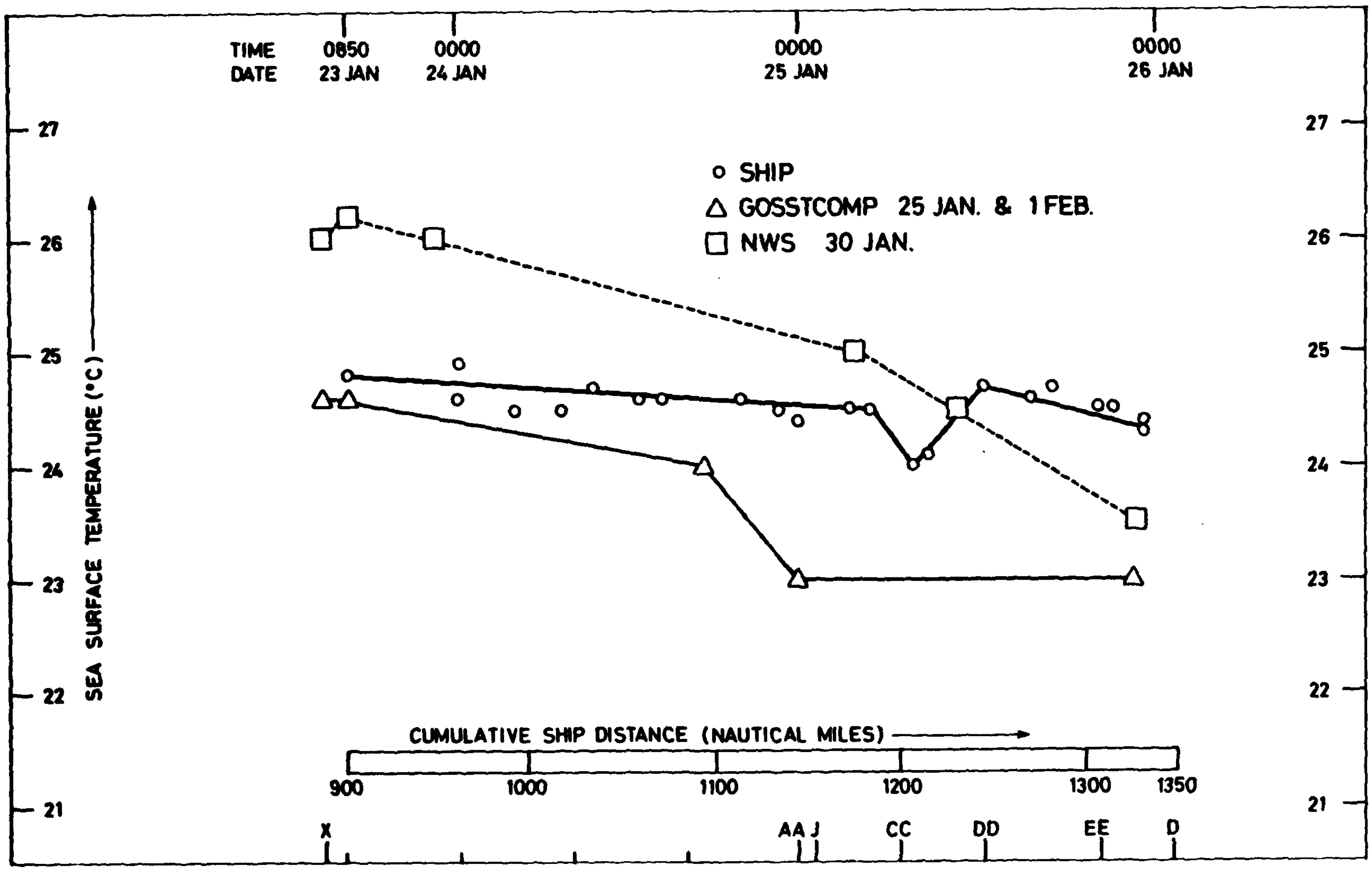

Fig. 11(b). Sea surface temperature (°C) vs cumulative ship distance (n.m.). Cruise R.V. Sprightly SP1/83 23-26 January, 1983.

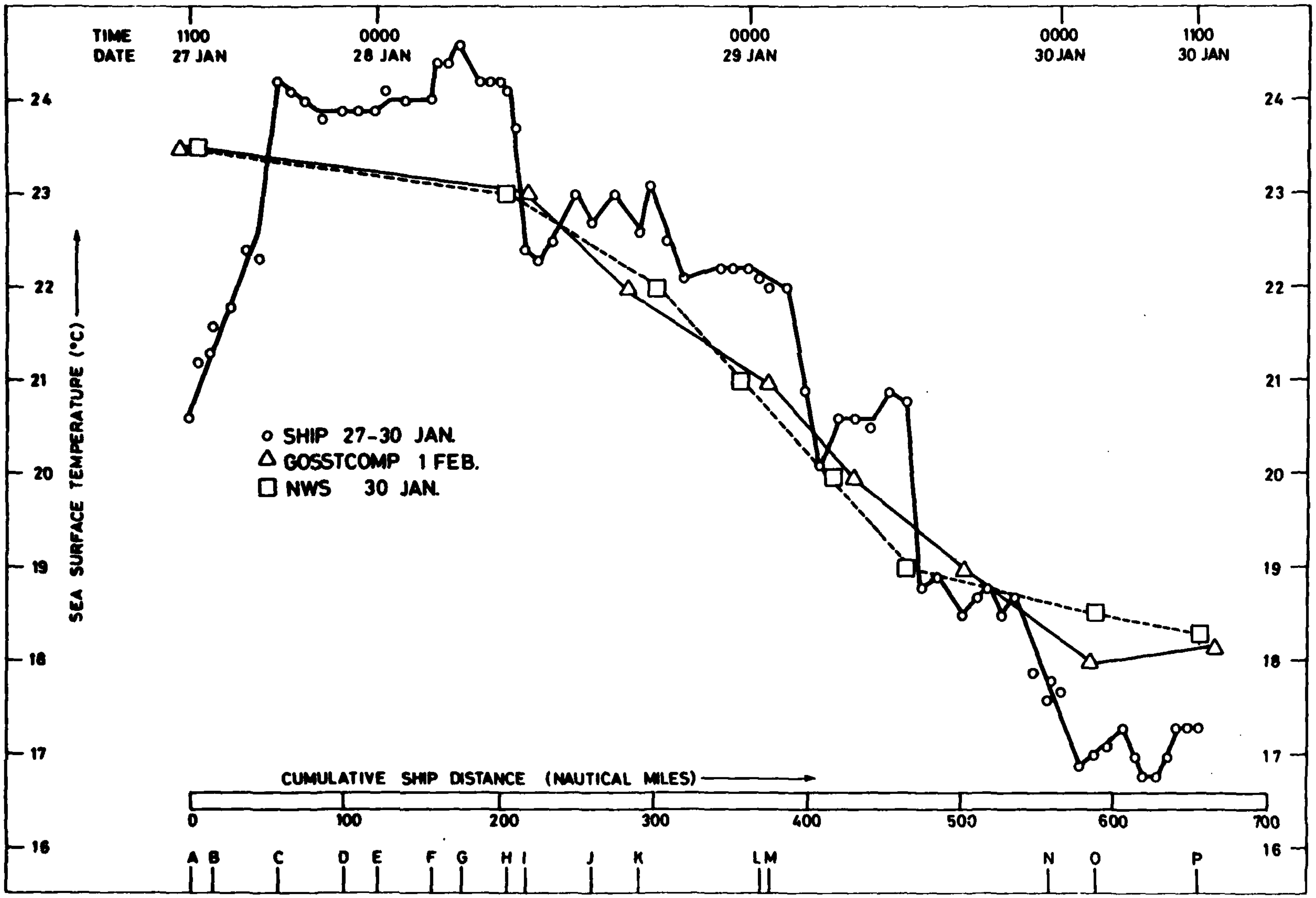

Fig. 12. Sea surface temperature (°C) vs cumulative ship distance (n.m.). Cruise R.V. Sprightly SP2/83 27-30 January, 1983.

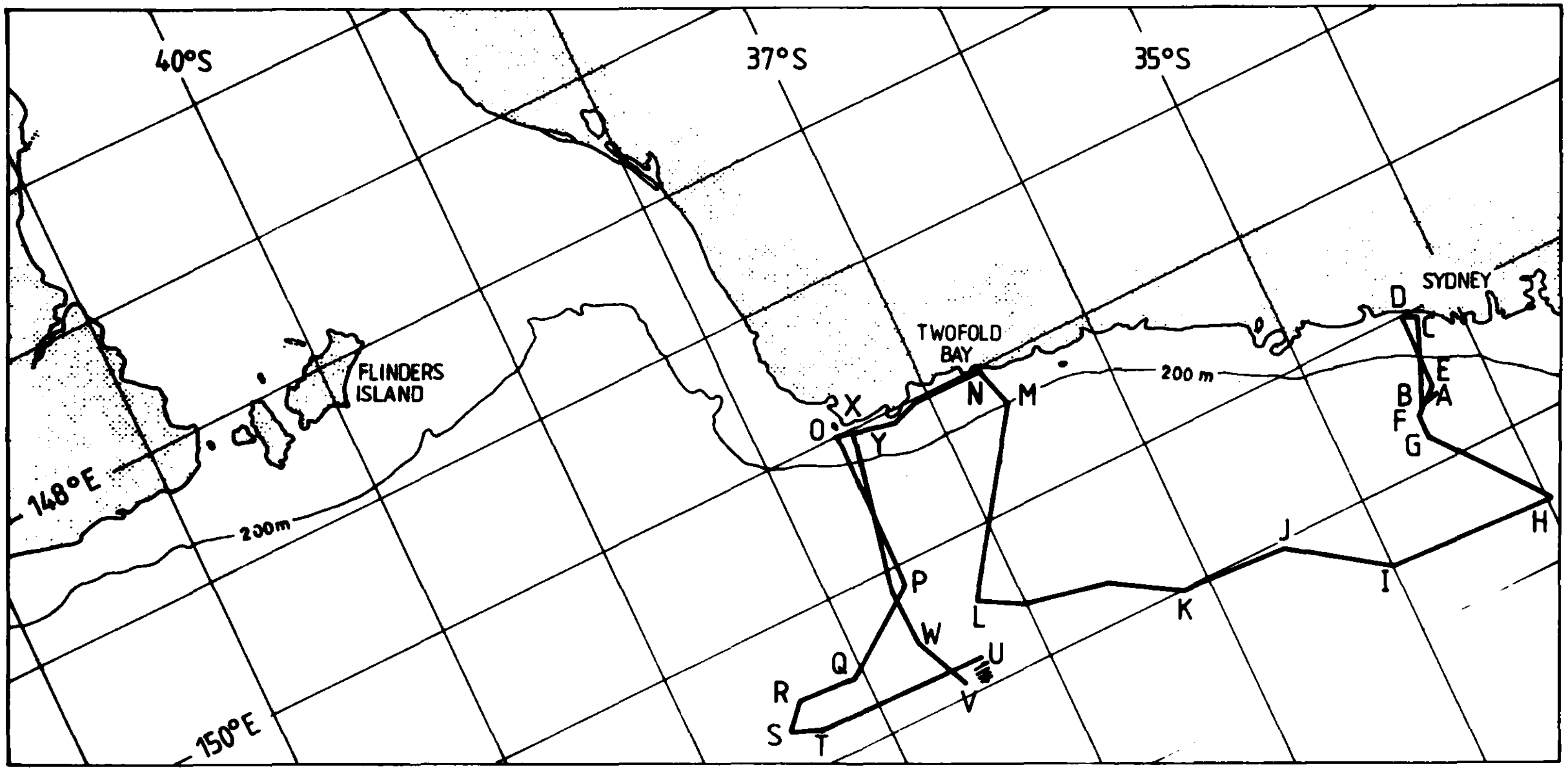

Fig. 13. Cruise track R.V. Sprightly SP 7/83 14-21 April 1983.

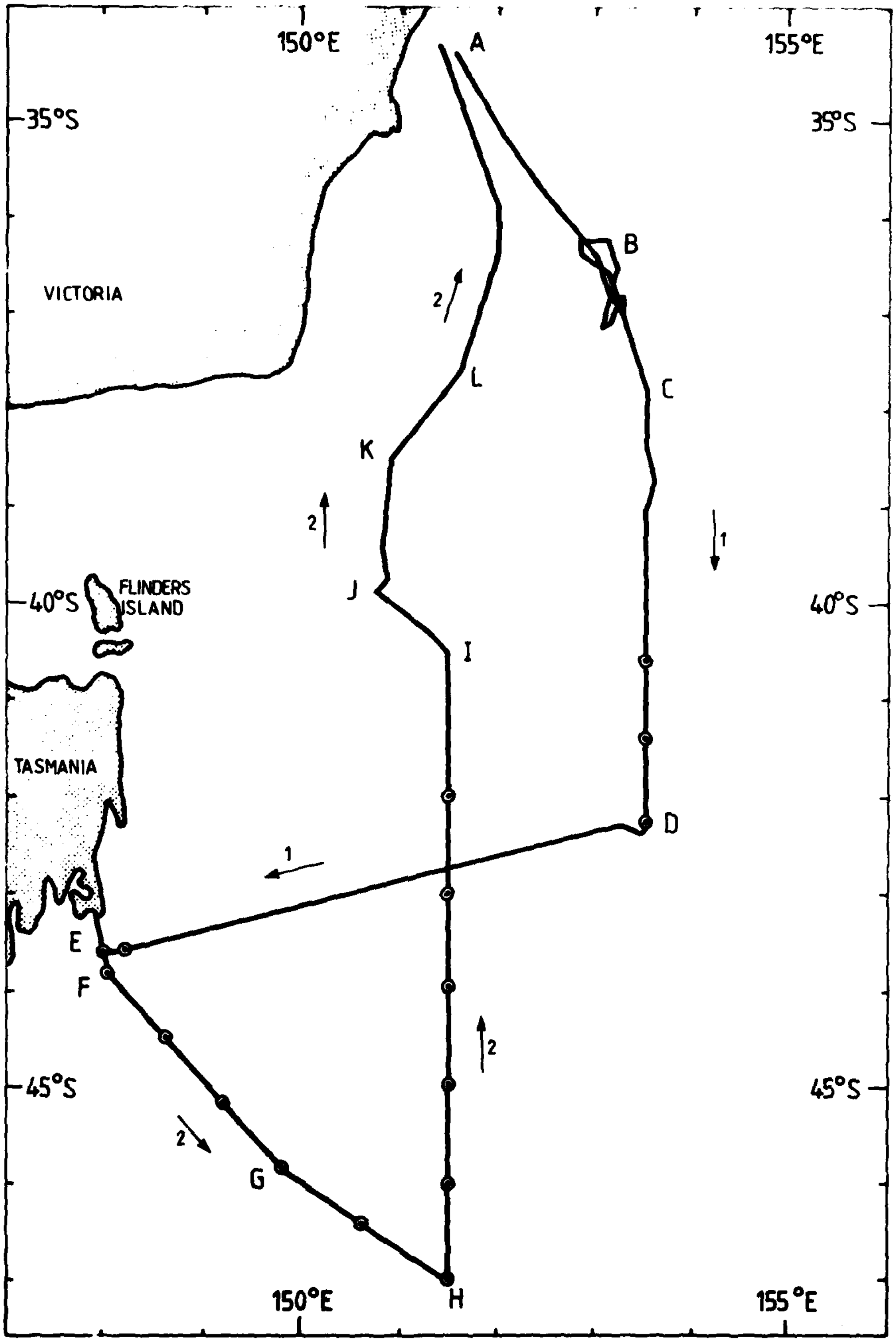

Fig.14. Cruise track RANRL 30/82 - HMAS Kimbla.
Leg 1. 15-23 Apr. Leg 2. 28 Apr. - 6 May 1983.

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16 Abstract

Sea-surface-temperatures (SST) obtained by thermosalinograph on five cruises during the period 23 September 1982 to 30 January 1983 in waters east and north-east of the Australian coastline are compared graphically with SST obtained from three sources of satellite data, GOSSTCOMP charts (Global Operational Sea Surface Temperature Computation), NWS charts (National Weather Service), and GMS (Geostationary Meteorological Satellite) tables. The data is plotted as temperature versus cumulative ship distance travelled. For these cruises fronts and features were seldom discernible in the satellite data but broad scale average trends were well shown. GOSSTCOMP was found to be the most reliable temperature indicator, often closely following the graph of highly smoothed ship temperature. NWS often tended to follow peak temperatures while GMS often overestimated SST by more than 3°C. Estimates are given on the use of absolute values of satellite SST in real-time analyses.

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